Central Valley Ground-Surface Water Model
Central Valley, California

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Prepared for

U.S. Bureau of Reclamation
California Department of Water Resources
California State Water Resources Control Board
Contra Costa Water District, California

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PREFACE

This report prepared for the United States Bureau of Reclamation (USBR), the California Department of Water Resources (DWR), the California State Water Resources Control Board (SWRCB), and the Contra Costa Water District (CCWD), contains a wealth of information relating to the Central Valley of California. To gather and assemble this information, a great deal of time and effort was spent by numerous persons. The study members responsible for this study were:

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In addition, we would like to acknowledge numerous local federal, state, and local agencies who provided assistance in data collection.

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Section 1

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1.0 INTRODUCTION

1.1 PROJECT BACKGROUND

Several groundwater models have been developed for portions of the California's Central Valley over the past decades. In the early 1980's, the United States Geological Survey (USGS) developed a groundwater model covering most of the Valley. More recently, Boyle Engineering Corporation under a contract with the California State Water Resources Control Board (SWRCB) developed a finite element model which simulates the interaction between surface water and groundwater using a six mile by six mile square horizontal grid and three layers to approximate the vertical variations of the aquifers in the valley (Boyle, 1987).

Subsequent to the SWRCB study mentioned above, the USBR, in conjunction with SWRCB, the California Department of Water Resources (DWR), and later, the Contra Costa Water District (CCWD), funded this work to further improve modeling capabilities and input data as applicable to the Central Valley. The resultant model is referred as the Integrated Groundwater and Surface Water Model (IGSM). The model as specifically applied to the Central Valley of California is referred to as the Central Valley Groundwater and Surface Water Model (CVGSM).

1.2 OBJECTIVES

The general objective of this study was to develop a Valley-wide groundwater model capable of predicting the response of the Valley's aquifers to variations in surface water supplies and groundwater demands as well as assessing the effects of these conditions on water quality in the Valley.

More specifically, the study objectives are:

- refine the model input data for the Central Valley to form a comprehensive hydrologic data base

- modify the existing model grid by refining the finite element mesh so that regional, subregional, and site-specific analysis can be performed by selecting a group of finite elements

- modify the CVGSM to take into consideration variable land uses in time and different crop mixes consistent with DWR's Consumptive Use Model data base

- develop a postprocessor capable of producing water budget results on a subregional basis

- confirm and/or refine pumpage estimates and distribution of groundwater pumping

- compile and analyze seepage losses for unlined canals to be included in the model simulation

- develop postprocessors to use the model results as input data for PROSIM and DWRSIM models (reservoir operation models for the Central Valley operated by USBR and DWR, respectively)

- establish the reliability of the model to predict groundwater elevations and streamflow through calibration and verifications using representative historic periods

- perform a sensitivity analysis on input variables that are considered to have a significant effect on the results

- determine what areas, if any, may be subjected to land subsidence due to overpumping during dry years

- review previous groundwater quality investigation on the Central Valley and determine if groundwater quality will be affected by overpumping in dry years

- identify other general and/or site-specific groundwater related problems such as water logging, high groundwater tables, overdraft, etc.

- provide documentation and training so that the model be acceptable and understood by USBR, SWRCB and DWR, thereby establishing a common ground (database and working assumptions) with regard to how those agencies simulate the Central Valley's groundwater resources.

1.3 STUDY AREA DESCRIPTION

The project study area covers the entire Central Valley of California that encompasses about 20,000 square miles and is shown in Fig. 1.1. The Valley is an almost flat alluvial plain extending more than 400 miles from near Redding in the north to near Bakersfield in the south. The width of the valley ranges from 20 to 70 miles with an average of 50 miles in most places. The Valley is

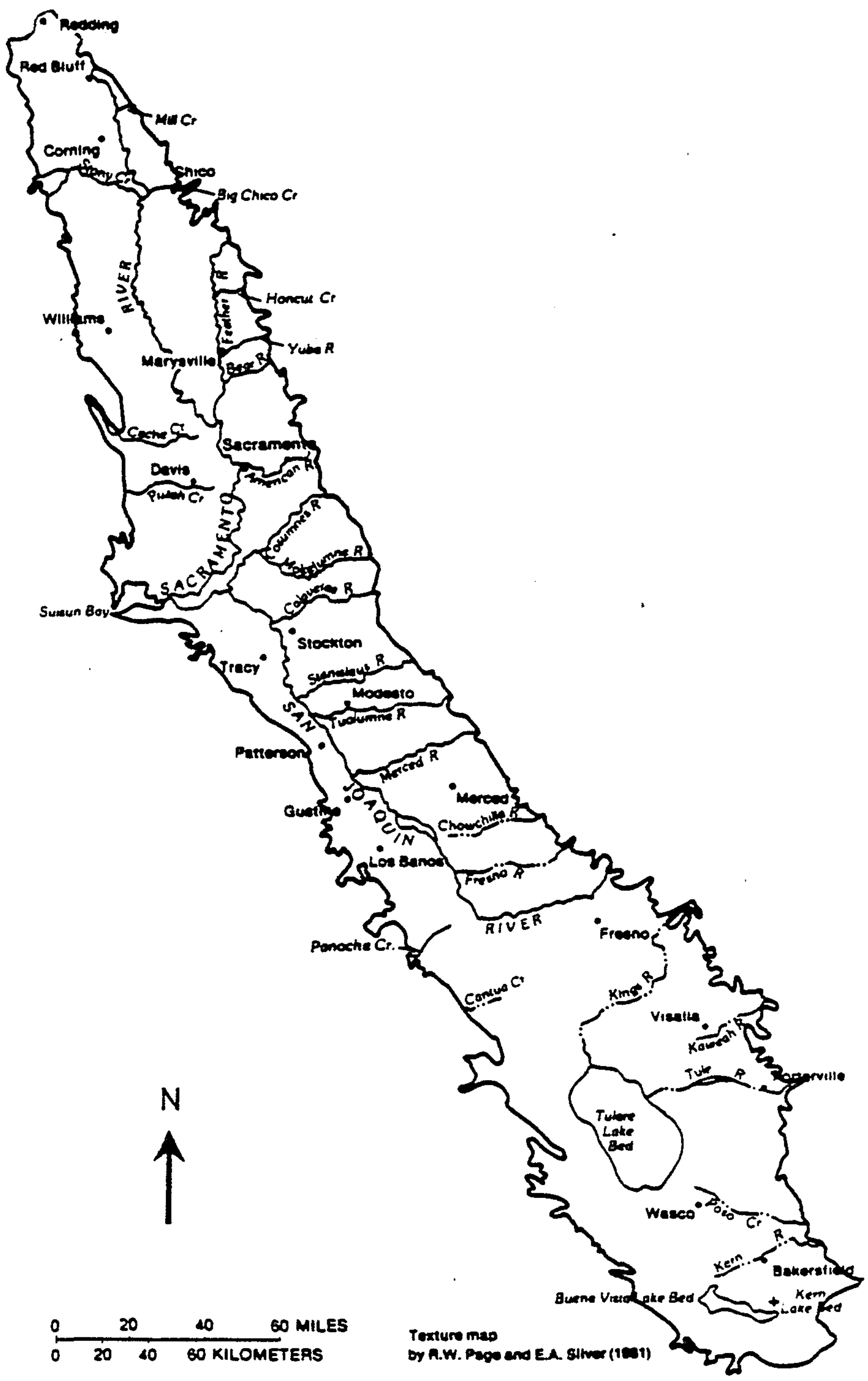

FIGURE 1.1

GEOGRAPHIC BOUNDARIES OF THE CENTRAL VALLEY surrounded by the Klamath mountains on the north, by a volcanic plateau of the Cascade Range on the northeast, by the Coastal Ranges on the west, by the Sierra Nevada on the east, and by the Coast Ranges and the Tehachapi mountains on the south.

The Central Valley is subdivided into two separate valleys that are named after the major rivers that drain the area. The northern one-third of the Central Valley is drained by Sacramento River and is called the Sacramento Valley and the southern two-thirds is drained by the San Joaquin River and is called the San Joaquin Valley. The area that joins the two valleys is known as Delta where the Sacramento and San Joaquin rivers meet and discharge through a natural outlet to Suisun Bay and San Francisco Bay.

For planning purposes, DWR has divided the state into 12 Hydrologic Study Areas (HSA). The Sacramento Valley is entirely contained within the Sacramento HSA. The San Joaquin Valley is divided into two hydrologic study areas - the San Joaquin HSA north of Fresno County, and the Tulare Lake HSA on the south. The Tulare basin is a closed hydrologic basin of interior drainage - with Kings, Tule, and Kern rivers draining to nearly dry depression areas that in the recent past contained Tulare Lake and Buena Vista Lake. The Central Valley thus consists of four hydrologic subareas - Sacramento, Delta, San Joaquin, and Tulare. The main focus of this study has been placed on the Sacramento, San Joaquin and Tulare areas.

The topography of the Central Valley is relatively flat as a result of millions of years of fluvial deposition of sediments from the surrounding mountain ranges. The elevations of the alluvial plain is generally just a few hundred feet above sea level with extremes ranging from a few feet below sea level to almost 1,000 feet above. The Sutter Buttes is the only prominent structure that rises abruptly to an altitude of about 2000 ft above the flat valley floor. It is a volcanic plug about 10 miles in diameter and is not considered a part of the groundwater basin. Some alluvial fans on the south and northwest perimeters of the Valley rise as high as 1800 ft at their apexes. The Kettleman Hills on the southwest is an anticlinal fold that restrict the movement of groundwater (Page, 1986) and is not considered a part of the groundwater basin of the Central Valley.

The economic importance of the Central Valley is tremendous. It is one of the largest agricultural areas in the country and the gross value of agricultural production in this area exceeds $10 billion. About 50% of the Central Valley (12,000 sq. miles) is irrigated land that uses nearly 30 million acre-ft of applied water annually. However, the distribution of natural water supply in the Central Valley is just the reverse of the water use, most of the precipitation occurs in the northern one third of the valley while about 80% of the water use is in the southern two-thirds. This disparity between the natural water supply and the water needs has resulted in excessive groundwater pumping that has caused significant land subsidence in the south. Excessive pumping from the Central Valley groundwater basin also poses a great threat to the overall water quality in the region. It is estimated that annual net water use in the Central Valley may increase by as much as 1.5 million acre-ft. Against this backdrop of uneven distribution of water, groundwater overdraft, land subsidence, and water quality degradation, an integrated effort should be made for the proper management and beneficial use of both surface water and groundwater. CVGSM is a prelude to this effort as it may be used to explore the need and the potentials of the conjunctive use throughout the Central Valley.

Section 2

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2.0 CENTRAL VALLEY GROUNDWATER SURFACE WATER MODEL: A SUMMARY

2.1 MODEL OVERVIEW AND DESCRIPTION

The general finite element model developed in this study is acronymed as IGSM (Integrated Groundwater and Surface Water Model) as it simulates the water flow both above and below the ground surface as well as their interactions through streams, canals, lakes, and soil matrix. This model may be viewed as a planning tool which can be used to simulate streamflows and groundwater movement on a large spatial and temporal scale. In this study, this model is applied to an area of about 20,000 square miles to simulate a 59 year period (1922-80) hydrology of surface water and groundwater flows and their interactions.

The IGSM is a very comprehensive hydrologic model in the sense that it integrates all the component processes of the hydrologic cycle and their interaction with one another in a single model. For a surface hydrologic system, it simulates evapotranspiration, direct runoff, infiltration and deep percolation resulting from rainfall and irrigation applied water. It also simulates streamflows and their interaction with groundwater. A groundwater simulation is based on a multi-layered finite element approach. The documentation and user's manual for IGSM prepared separate from this report includes detailed descriptions for theories and approaches employed in the model.

2.2 MODEL AREA

<u>Model Grid:</u>

A two-dimensional finite element grid network was developed to model the groundwater flow in the Central Valley aquifer system. The entire model area (19,710 square miles) is subdivided into 1,392 finite elements with an average size of about 14 square miles. Both 4-sided and 3-sided elements were used in congruence with the model grid development criteria established *a priori*. The notable features of the model grid are:

- model boundary matches the geologic boundary of the Central Valley.
- grid lines match major streams and creeks that are included in the simulation, and are parallel to streamflow direction to incorporate the surface drainage pattern.

- grid orientation generally follows groundwater streamlines to incorporate the subsurface drainage pattern.

- element meshes are relatively finer in the vicinity of steep groundwater gradients to account for faster rate of changes in groundwater elevations.

- a thin strip of elements are used to incorporate the discontinuities in the GW levels near the major fault lines.

- element boundary lines match the predefined boundary lines of 21 model subregions.

The total number of finite element nodes in the groundwater grid network is 1,393. The X-Y coordinates of each node are obtained by digitization on a USGS base map of the State of California. The origin of the X-Y coordinate system was taken arbitrarily at the intersection of 35° latitudinal line and 750,000 UTM line (between 120° and 121° longitude). The X-axis is collinear with the 35° latitudinal line while the Y-axis is collinear with the UTM line. The model grid is presented in Figs 2.1 and 2.2, showing respectively the element numbers and the node numbers.

The surface water flow is modeled by using 1-dimensional line elements along the stream. These line elements are always collinear with an edge of two dimensional groundwater grid element. A total of 431 nodes are used to simulate streamflow in the 72 reaches of 42 modeled streams. The stream reaches and the stream nodes used in the model are shown in Fig 2.3.

Model Subregions:

In order to analyze the model results on a smaller spatial scale, the study area was divided into several subregions. The State Department of Water Resources's Division of Planning has divided the Central Valley into several planning areas called Depletion Study Area (DSA). The current model utilizes this subdivision to analyze the water budget on a local scale by incorporating the DSAs as the model subregions. In the northern part of the Central Valley, 9 DSAs are incorporated as 9 model subregions. In case of the Redding Basin (DSA 58), only the portion that is within the model geologic boundary is incorporated as a subregion. In the case of DSA 65, an adjacent land area that has no DSA designation is added to the corresponding model subregion. In the south, however, the delineation of the DSAs was found to be inadequate as the entire San Joaquin Valley is divided into only two DSAs -- DSA 49 (San Joaquin Valley above Vernalis) and DSA 60 (Tulare Lake Basin). For the purpose of making a detailed analysis of the surface water and groundwater budget on a smaller spatial scale, these two DSAs were subdivided into 12 subregions. This division was made with proper consideration to the hydrologic boundaries as well as the water

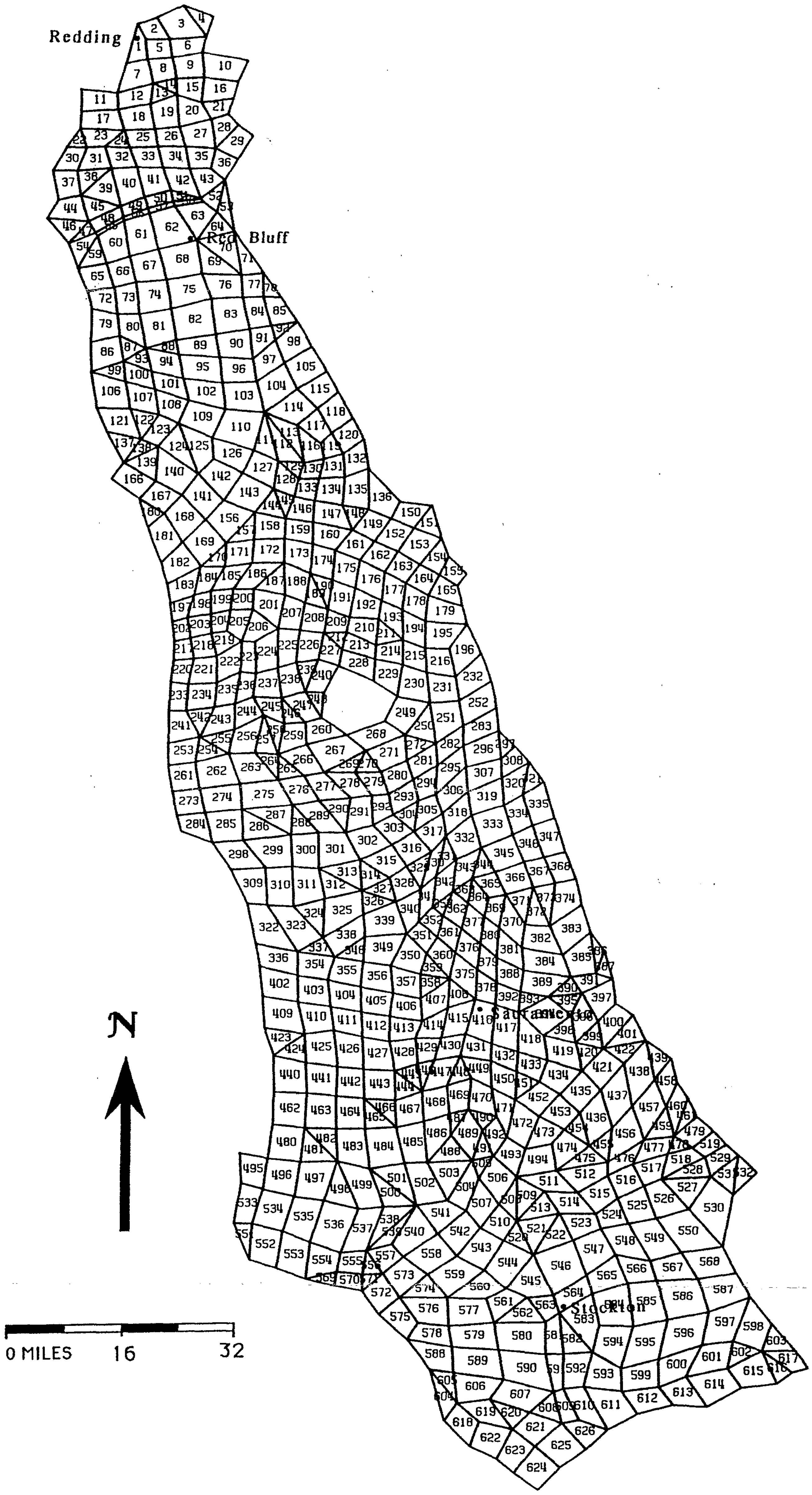

FIGURE 2.1(a)

MODEL ELEMENTS
IN
SACRAMENTO VALLEY

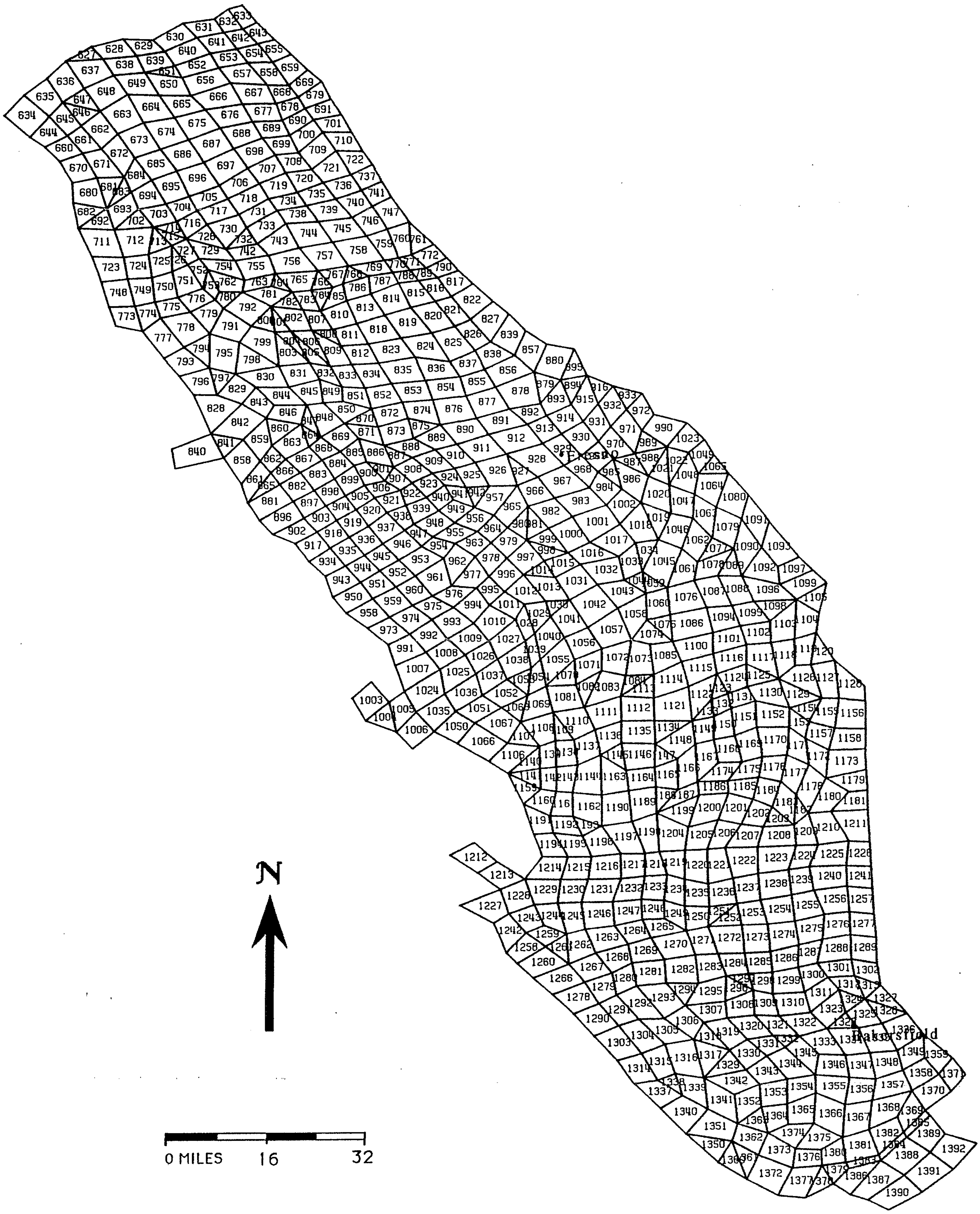

FIGURE 2.1(b)

MODEL ELEMENTS
IN
SAN JOAQUIN VALLEY

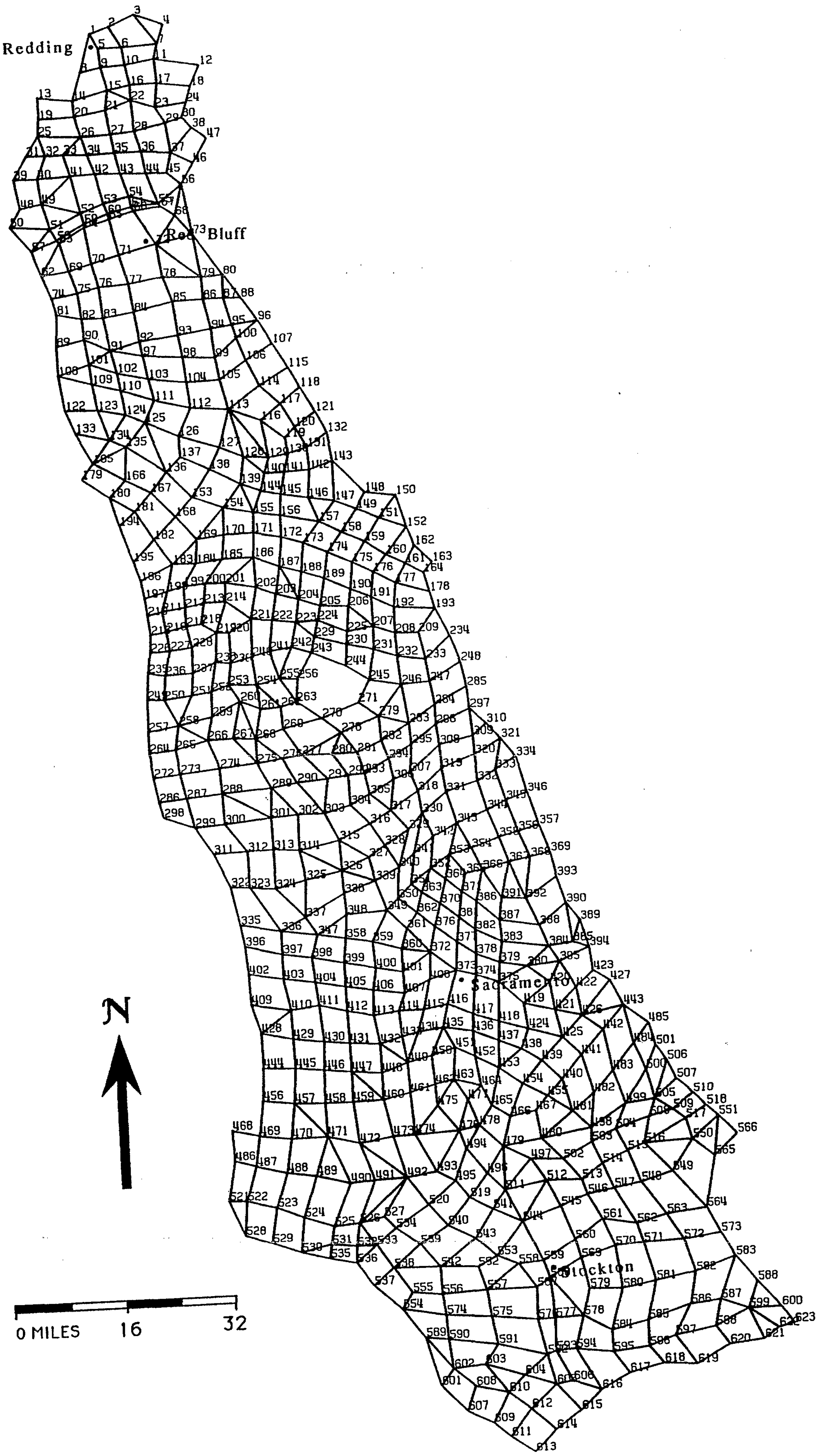

FIGURE 2.2(a)

MODEL NODES
IN
SACRAMENTO VALLEY

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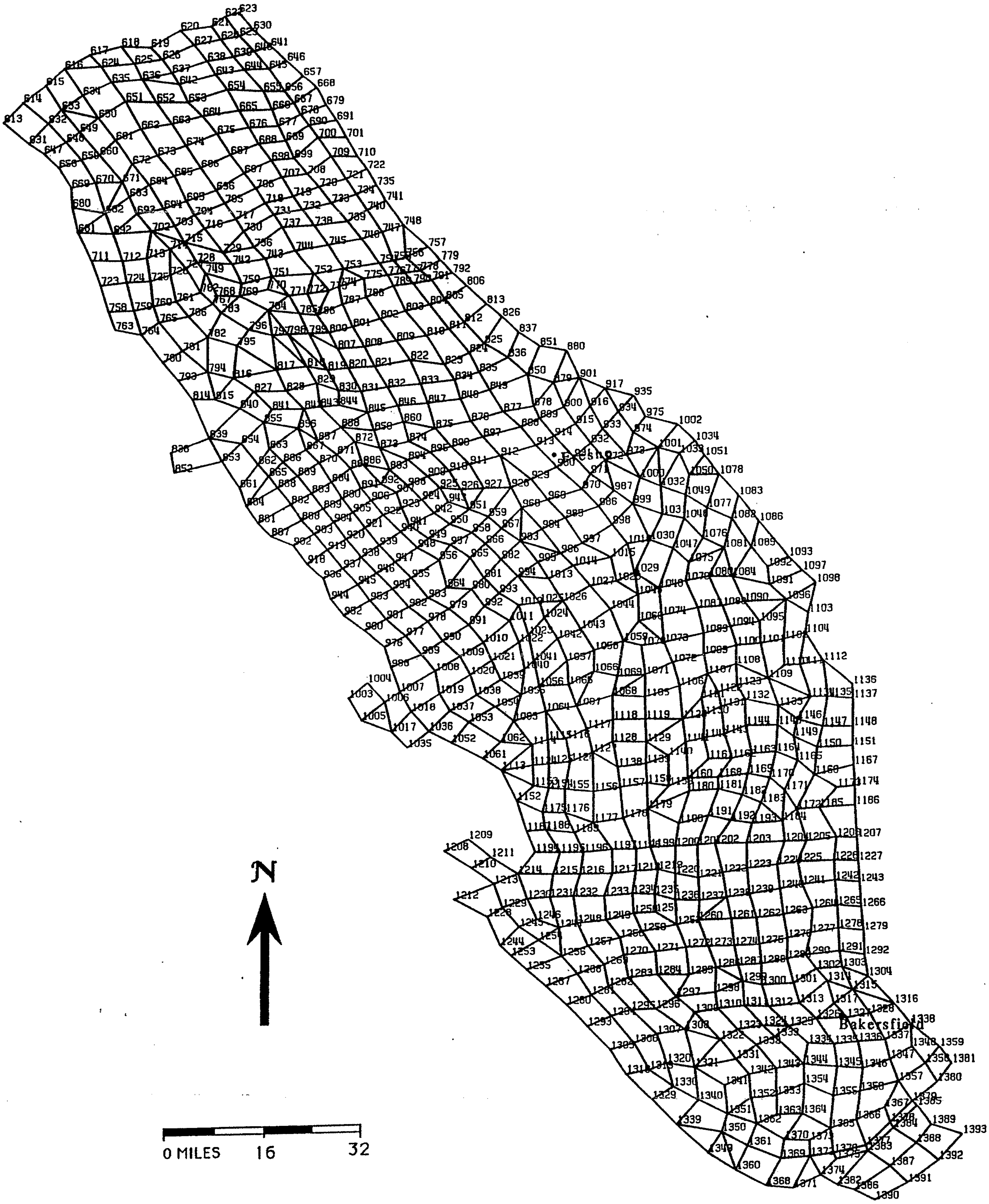
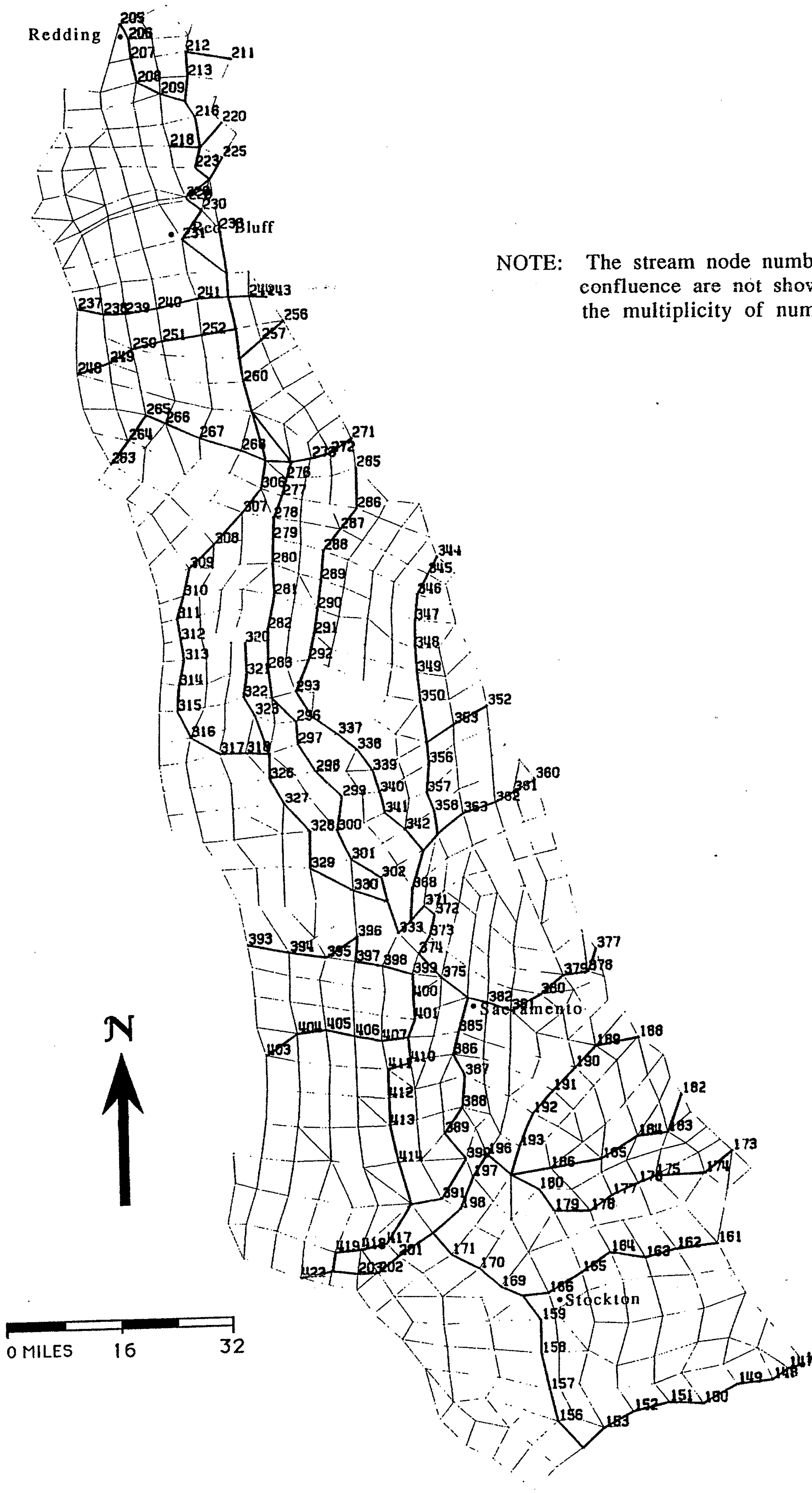


FIGURE 2.2(b)

MODEL NODES
IN
SAN JOAQUIN VALLEY

NOTE: The stream node numbers at the confluence are not shown due to the multiplicity of numbers.



FIGRUE 2.3(a)

MODEL STREAM NODES
IN
SACRAMENTO VALLEY

NOTE: The stream node numbers at the confluence are not shown due to the multiplicity of numbers.

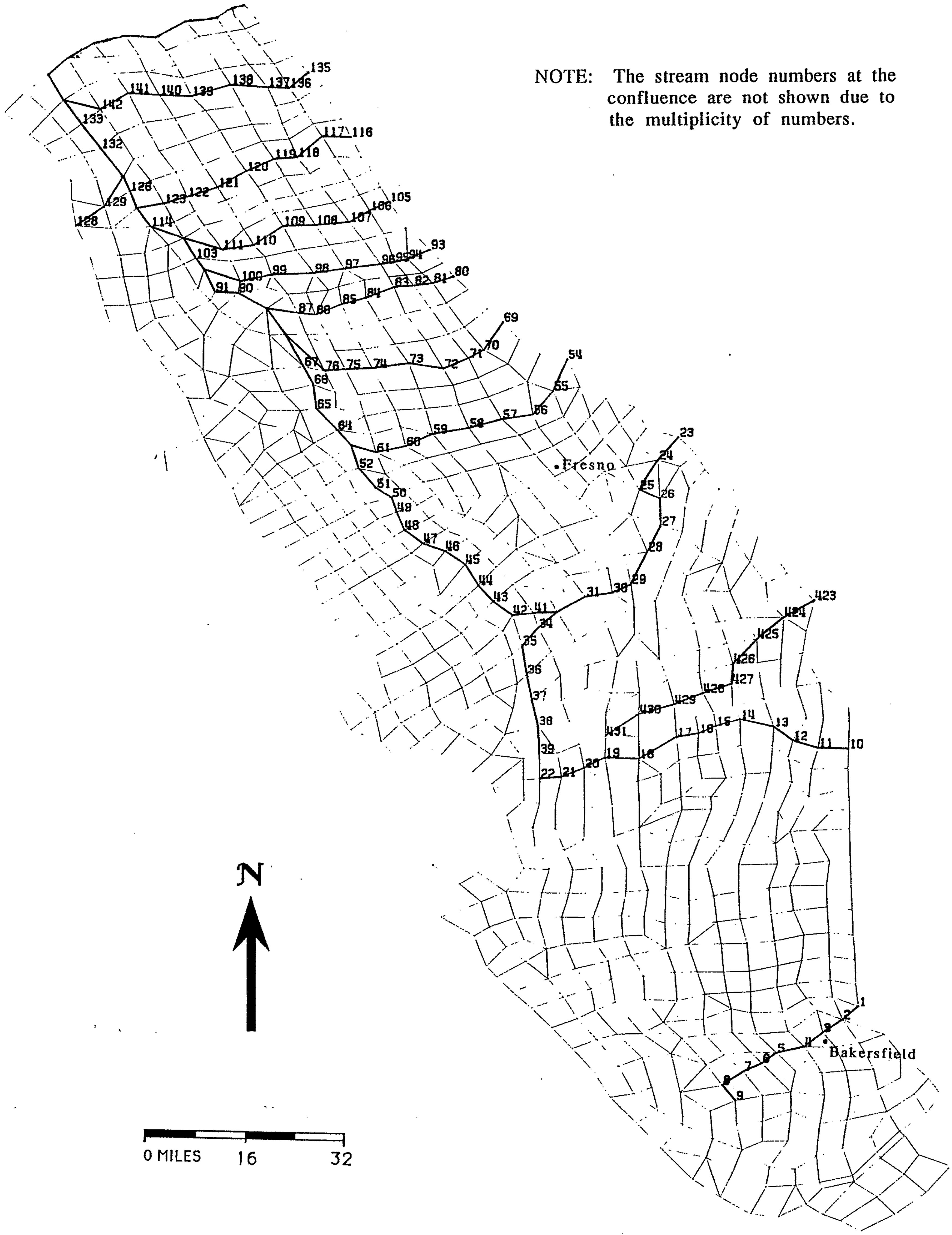


FIGURE 2.3(b)

MODEL STREAM NODES
IN
SAN JOAQUIN VALLEY

district/agency boundaries. The 21 model subregions are shown in Fig 2.4. It should be noted that DSA 55 (Delta area) is included in the model area for the purpose of developing appropriate boundary conditions required for the model. Hydrologic and water use data used for DSA 55 were based on existing available information and no effort was made to refine them within the scope of this study.

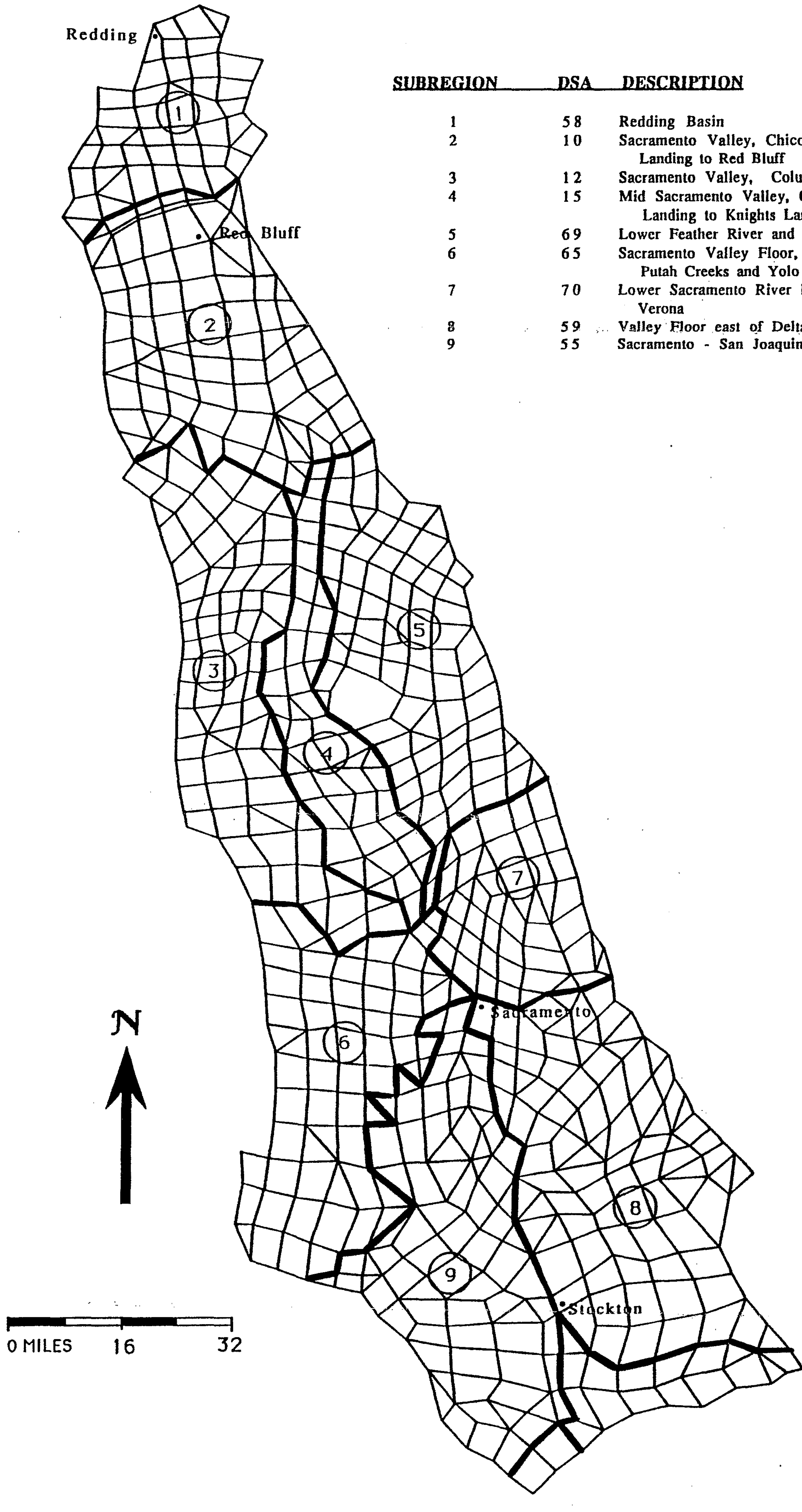
2.3 SUMMARY OF INPUT/OUTPUT DATA

Input Data:

The developed groundwater and surface water model is a very data-intensive model. A considerable amount of time and effort was devoted to the collection, compilation, preparation, and validation of the input data required by the model. As a result, the input files of this model, when combined together, provides perhaps the most comprehensive set of water resources data for the Central Valley of California. The computer code was specially designed to handle this extremely large data base. As a result, a substantial portion of the total execution time of the model is spent on the data management. Table 2.1 gives a comprehensive list of input data with reference to its class, type, spatial/temporal scale, and sources.

Output Data:

The output of the model is custom designed to meet the needs of different types of users -from groundwater modelers to soil scientists, hydrologists to water resources planners, water contracting agencies to water quality control boards. Post processor programs are linked with the main module to provide the modeler with different types of water budget tables as well as the graphical information on the water level fluctuations with time at a specified node and specified layer of the aquifer system. The program is so designed that it will automatically compare the water level fluctuation at the specified node with that of a neighboring well for which the data is stored previously and provide a superposed graph for both sets of data at the same scale. To minimize the use of disk storage, the user has the option to specify what types of output he/she wants to generate. The desired outputs can be generated either on an annual or on a monthly basis and a time window for which the outputs are wanted can also be specified. These important facets, apart from reducing the disk storage, also help reduce the model run time to a certain extent. Table 2.2 provides a summary of the output that can be generated. See the user's manual for further details.



SUBREGION	DSA	DESCRIPTION
1	58	Redding Basin
2	10	Sacramento Valley, Chico Landing to Red Bluff
3	12	Sacramento Valley, Colusa Trough
4	15	Mid Sacramento Valley, Chico Landing to Knights Landing
5	69	Lower Feather River and Yuba River
6	65	Sacramento Valley Floor, Cache and Putah Creeks and Yolo Bypass
7	70	Lower Sacramento River below Verona
8	59	Valley Floor east of Delta
9	55	Sacramento - San Joaquin Delta

FIGURE 2.4 (a)

MODEL SUBREGIONS
IN
SACRAMENTO VALLEY

SUBREGION	DSA	DESCRIPTION
10	49A	Valley Floor west of San Joaquin River
11	49B	Eastern San Joaquin Valley above Tuolumne River
12	49C	Eastern Valley Floor between Merced and Tuolumne Rivers
13	49D	Eastern Valley Floor between San Joaquin and Merced Rivers
14	60A	Westlands
15	60B	Mid-Valley Area
16	60C	Fresno Area
17	60D	Kings River Area
18	60E	Kaweah and Tule River Area
19	60F	Western Kern County
20	60G	Eastern Kern County
21	60H	Kern River Area

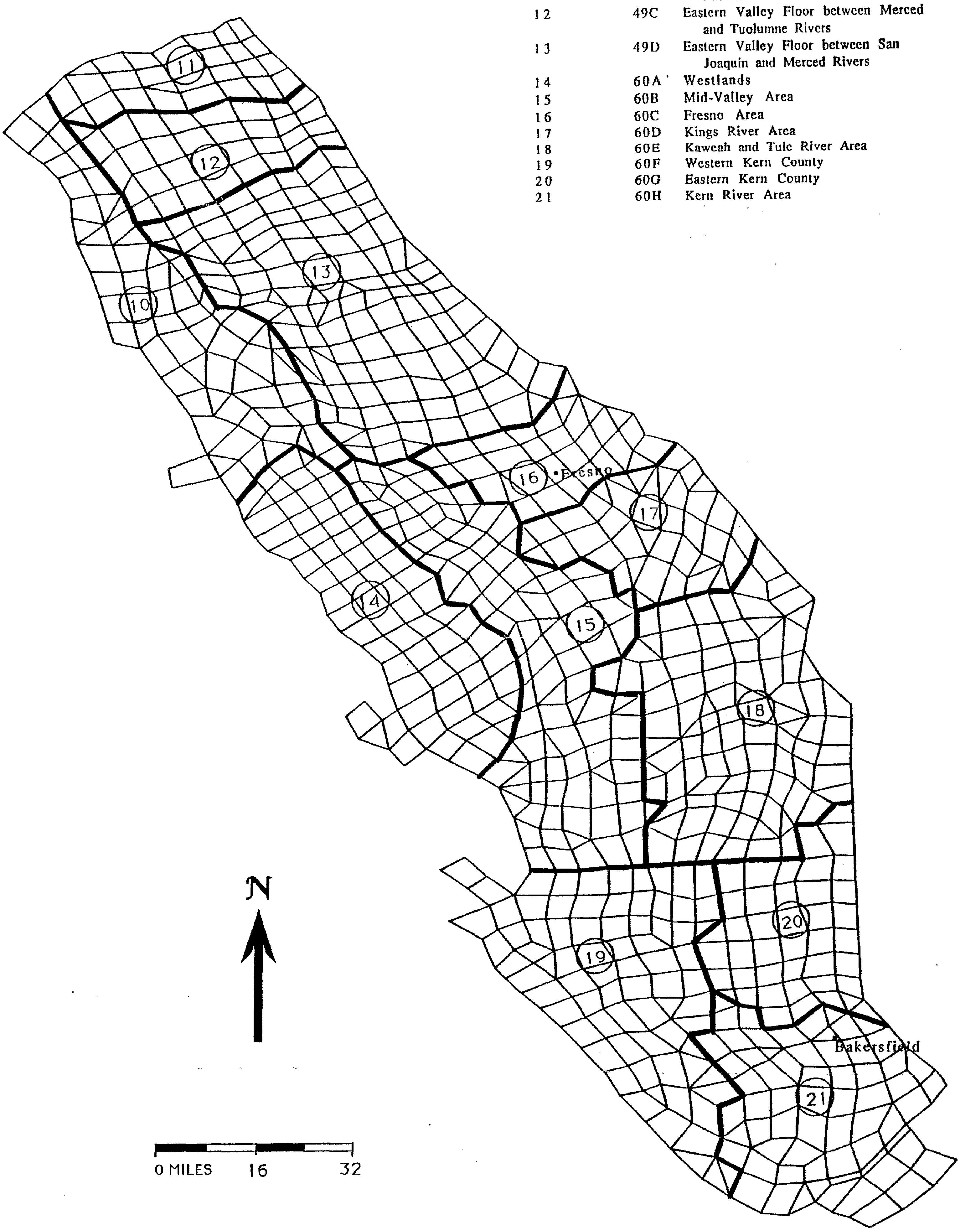


FIGURE 2.4(b)

MODEL SUBREGIONS
IN
SAN JOAQUIN VALLEY

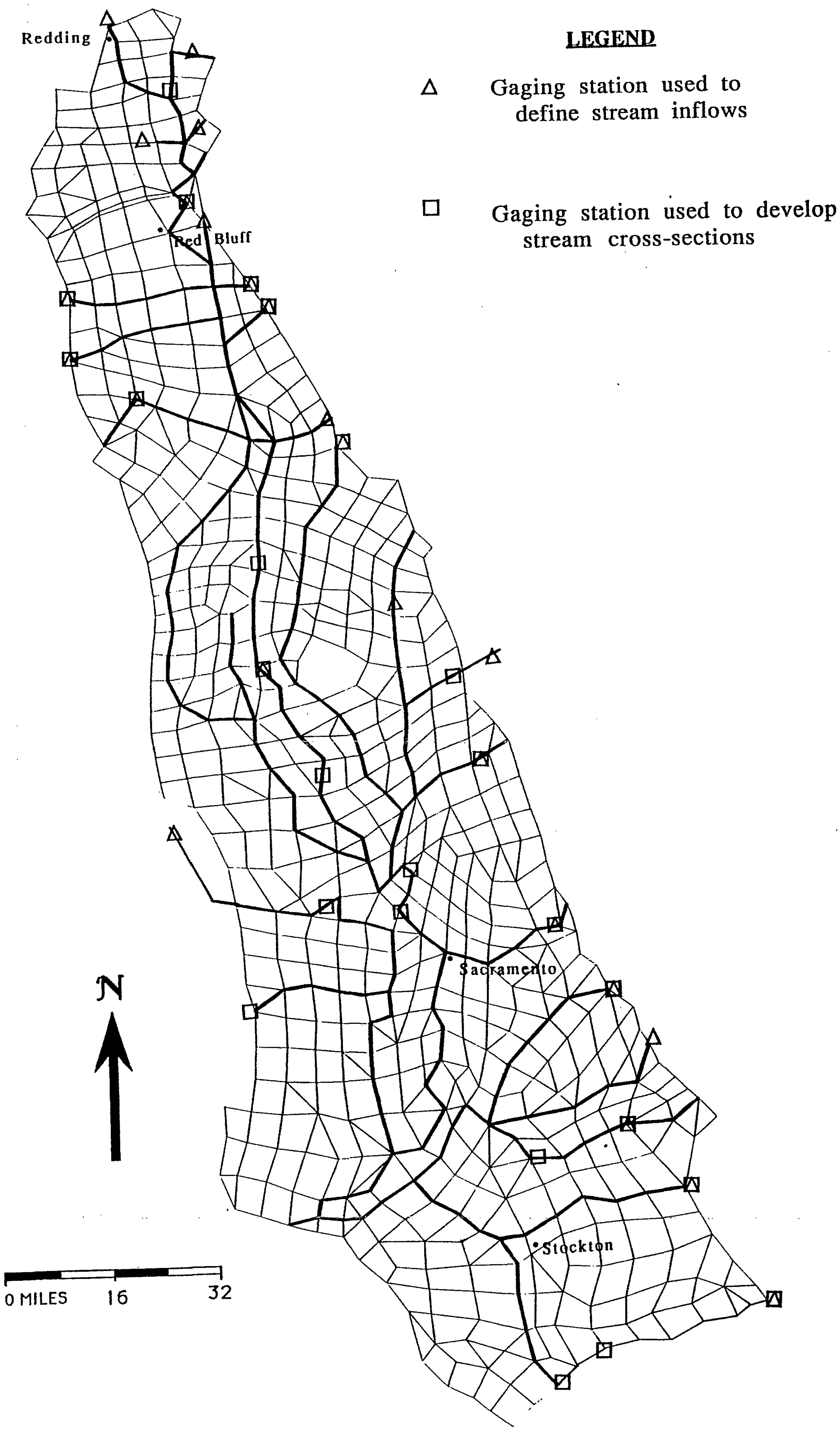


FIGURE 3.4(a)

STREAM CROSS-SECTION AND GAGING STATION LOCATIONS IN SACRAMENTO VALLEY

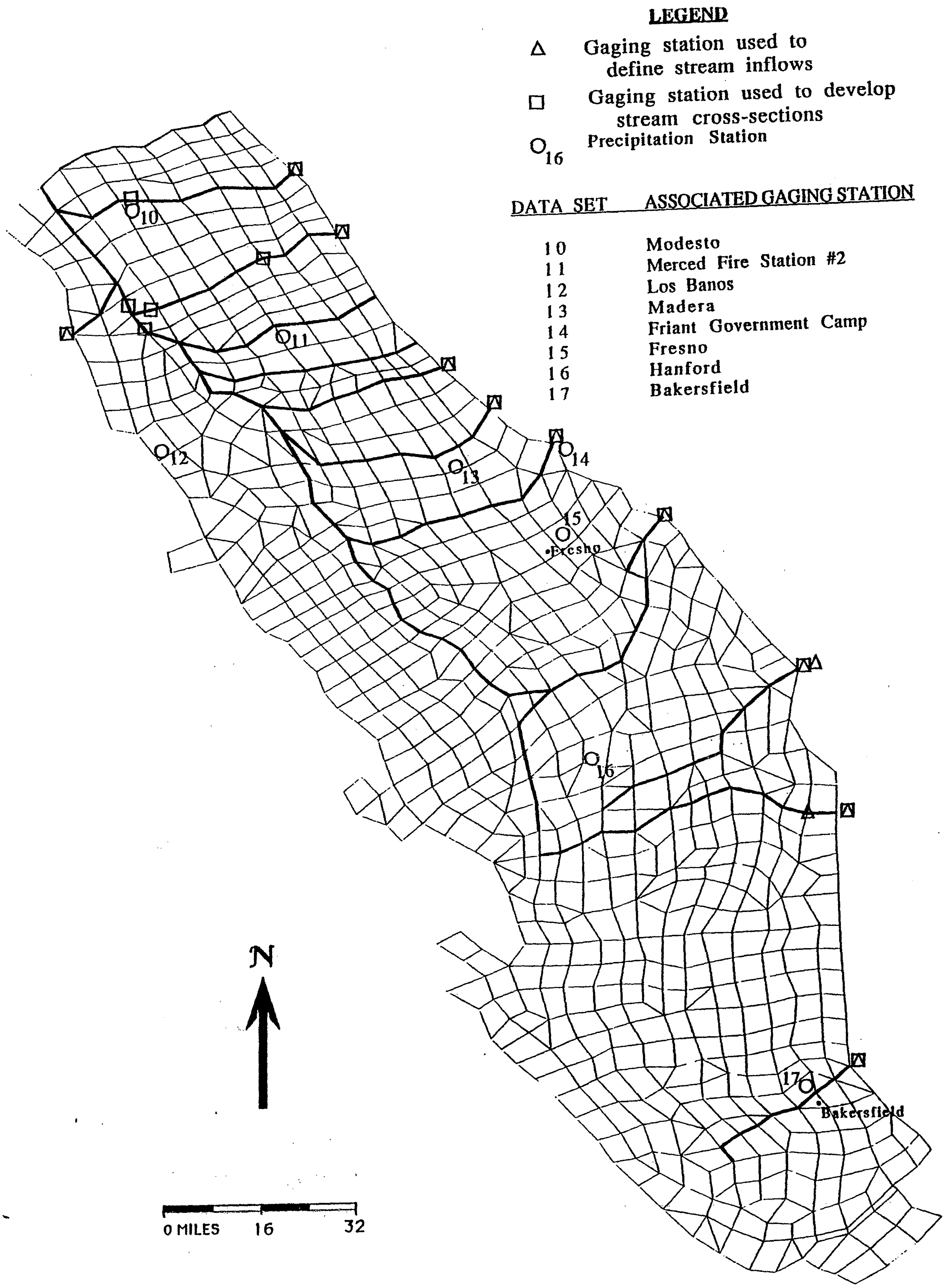


FIGURE 3.4(b)

STREAM CROSS-SECTION, GAGING STATION, AND PRECIPITATION STATION LOCATIONS IN SAN JOAQUIN VALLEY

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TABLE 2.1

SUMMARY OF INPUT DATA

Data Group	Data Item	Spatial Scale	Time Scale	Source	Input File Name
		Data Characteristics			
Model Characterization	•Element configuration	Element	Invariant	JMM	CNJELEM.DAT
	•Nodal coordinates	Node	Invariant	USGS Maps	CNJXY.DAT
	•Stream configuration	Stream Node	Invariant	USGS Maps	CNJSTRM.DAT
	•Subregion definition	Element	Invariant	DWR, SWRCB, USBR, JMM	CNJCHRC.DAT
Geohydrology/ Geography	•Stratigraphy	Node	Invariant	USGS, Well Logs, Previous Studies	CNJSTRA.DAT
	•Stream Cross-Sections	Stream Node	Invariant	USGS, Previous Studies	CNJSTRM.DAT
	•Drainage Pattern	Element	Invariant	USGS Maps	CNJCHRC.DAT
	•Aquifer Parameters	Node/Element	Invariant	USGS and DWR Studies, Reports, JMM	CNJPARM.DAT
Hydrology/ Climatology	•Rainfall	Gaging Station/ Region	Monthly	NOAA, Depletion Model (DWR)	CNJPRCP.DAT
	•Rainfall Distribution	Element	Invariant	Isoheytal Map (DWR)	CNJCHRC.DAT
	•Soil Classification	Element	Invariant	SCS, Other Reports	CNJCHRC.DAT
	•Evapotranspiration	Region	Monthly	Consumptive Use Model (DWR)	CNJET.DAT
	•Upstream Inflow	Upstream Stream Node	Monthly	USGS, Depletion Model (DWR)	CNJINFL.DAT
Land Use	•Land Use Distribution	Element	Annual	DWR, USBR	CNJLND.DAT
	•Crop Acreage	Region	Annual	Consumptive Use Model	CNJCRP.DAT
Water Use	•Surface Water Diversion	Region	Monthly	USBR, DWR, Depletion Model, Districts	CNJSWDV.DAT
	•Diversion/Delivery Location, Conveyance Losses	Region	Invariant	Maps, Reports, etc.	CNJSPEC.DAT
	•Groundwater Pumping	Region	Monthly	USGS, Power Records, SWAM	CNJPUMP.DAT
	•Pumping Distribution	Element	Invariant	USGS, Power Records	CNJSPEC.DAT
	•Urban Water Use	Region	Monthly	Consumptive Use Model (DWR)	CNJURB.DAT
Other	•Initial Conditions	Node	Invariant	Water Level Maps, Previous Studies, JMM	CNJINIT.DAT
	•Boundary Conditions	Node	Invariant	JMM	CNJBOND.DAT

TABLE 2.2

SUMMARY OF OUTPUT OPTIONS

- **Regional, Subregional Groundwater Budget**
  Provides annual/monthly deep percolation, stream gain/loss, pumpage/recharge, subsurface inflow, change in storage, end of time period storage.

- **Regional, Subregional Surface Water Budget**
  Provides annual/monthly upstream/downstream flows, direct runoff from rain, agricultural/urban return flows, gain from groundwater, surface water diversions, bypass/flow adjustments, and the diversion shortages, if any.

- **Regional, Subregional Soil Moisture Budget**
  Provides annual/monthly rainfall, evapotranspiration, direct runoff, percolation, return flow and irrigation demand for three land use areas (agricultural, municipal, and undeveloped as appropriate) separately.

- **Regional, Subregional Land and Water Use Budget**
  Provides annual/monthly ag/urban acreage and demand, groundwater pumping, surface water diversions, shortages, recoverable/nonrecoverable losses, and import/export from one subregion to another.

- **Groundwater Levels at Selected Model Node**
  The output is in a format that is specially designed to mimic the shape of the model area so that it can be directly used for calibration purposes. Also, the groundwater level hydrographs can be drawn from this data using a post processor program.

- **Groundwater Levels at Each Model Node**
  For a more detailed analysis, a post processor program can generate the water level contours from this set of data.

- **Streamflows Selected/All Stream Node**
  Provides a helpful tool for calibration. Also it can be used for water contracting/regulatory purposes as it gives the information about the availability of streamflow at a particular location at a particular time. A post processor program can generate the time series graph of the data at a stream node and compare it with time the data at a neighboring stream gaging station.

- **Boundary Inflows/Outflows**
  This can be used for water quality simulation, (e.g. to study the potential and dangers of salt water intrusion).

- **Diversions, Shortages by Each Diversion**
  Provides detailed information about the diversions and shortages on an individual basis.

Section 3

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3.0 MODEL INPUT DATA

3.1 GEOHYDROLOGY/GEOGRAPHY

Geology:

The Central Valley of California is a northwest trending asymmetric trough 400 miles long and averaging 50 miles in width. It is bounded on the west by pre-Tertiary and Tertiary semi-consolidated to consolidated marine sedimentary rocks of the Coast Ranges. These faulted and folded sediments extend eastward beneath most of the Central Valley, and when they contain water, it is usually saline. The east side of the valley is underlain by pre-Tertiary igneous and metamorphic rocks of the Sierra Nevada. Only small quantities of water are extracted from the joints and cracks of these basement rocks. The important geologic units are the unconsolidated to semi-consolidated non-marine sediments that range in age from Miocene (13-25 million years old) to recent. Many faults and folds exist in the Central Valley. The available information suggests that most do not obstruct groundwater flow. The Red Bluff Arch and the White Wolf Fault are the only two groundwater barriers that are within the model boundary. The Red Bluff Arch in the northern end of the Sacramento Valley separates the Redding groundwater basin from the Sacramento Valley groundwater basin and consists of a series of northeast trending anticlines and synclines. The White Wolf Fault is an oblique slip fault in Southern San Joaquin Valley which inhibits the northward flow of groundwater. These groundwater flow barriers and associated discontinuities in the water levels are represented in the model by a very fine finite element mesh in the vicinity. Since the Sacramento Valley and the San Joaquin Valley are very different in their geohydrologic characteristics, they are discussed separately below with special reference to aquifer characteristics.

Sacramento Valley:

During the geologic period of deposition, as much as 10 vertical miles of sediment have accumulated in the Sacramento Valley. Alluvium deposits exist throughout the valley in the form of alluvial fans, stream channel deposits, and flood plain deposits as shown in Fig. 3.1. No extensive confining layers exist in the Sacramento Valley, but locally confined and semi-confined aquifers do provide freshwater to wells. Unconfined aquifers provide much of the freshwater in the Sacramento Valley. Under predevelopment conditions, the groundwater flow in both the confined and unconfined aquifers was from the flanks to the valley axis, then south towards the Delta. However, recent development activities and the associated increased pumping has induced man-made changes in the natural groundwater flow patterns. The chief water-bearing deposits of the Sacramento Valley include: Mehrten, Tuscan, Tehama, Laguna, Fair Oaks, Red Bluff, and Victor formations and Fanglomerate. The Mehrten Formation generally consists

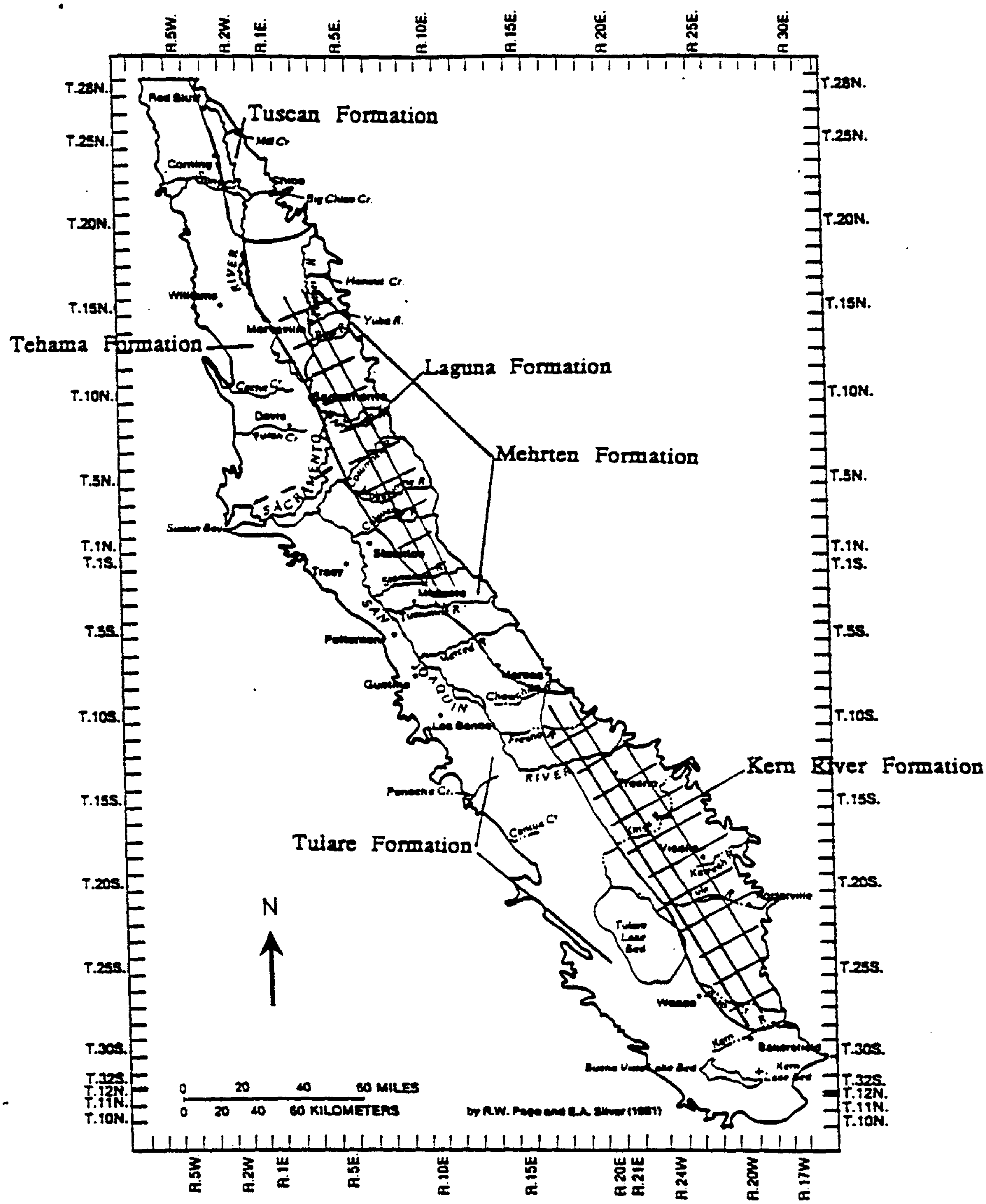

FIGURE 3.1

APPROXIMATE GEOGRAPHIC BOUNDARIES OF
MAJOR WATER BEARING
UNITS IN THE CENTRAL VALLEY

C —0 3 8 3 4 2

of water bearing volcanic sands and clays and impermeable tuft breccias. The Tuscan Formation is a volcanic conglomerate that appears in well logs as black sands and tuffaceous clays. The Tehama Formation is a highly variable mixture of locally cemented clay, silt, sand, and gravel. The Laguna Formation is a non-volcanic assemblage of granitic sands, silts and clays with some gravel deposits. The Fair Oaks Formation is similar to the underlying Laguna Formation. The Fanglomerate consists of volcanic debris eroded from the Tuscan Formation that is locally cemented to form sandstones and conglomerates. The Red Bluff Formation overlies the Tehama Formation and consists of poorly sorted gravelly deposits in a red silty clay matrix. The Victor Formation overlies the Fair Oaks Formation and Laguna Formation and contains granitic sands, silts and clays.

San Joaquin Valley:

The San Joaquin Valley is filled with up to 6 vertical miles of sediment. In the San Joaquin Valley, fresh groundwater is produced from wells tapping confined and unconfined aquifers. Fresh water is found both above and below the Corcoran Clay of the Tulare Formation which acts as the main confining layer in the San Joaquin Valley. Locally, saline water can be found both above and below the Corcoran Clay. Under predevelopment conditions, groundwater flow in the San Joaquin Valley was from the valley flanks to the axis, then north towards the Delta. Large scale groundwater development in the south has modified the natural flow pattern creating cones of depressions in major pumping areas.The chief water-bearing deposits of the San Joaquin Valley are Kern River Formation (generally a poorly sorted mixture of granitic sands, silt, clay and gravel), Mehrten Formation, Tulare Formation (unconsolidated, poorly sorted clays, silts, sands and gravel originating from the Coast Ranges), and Holocene alluvium. The Tulare Formation contains the Tulare Lake Bed deposits from which many clay beds, including the Corcoran Clay, of the San Joaquin Valley originate.

Model Stratigraphic Data:

Most of the stratigraphic input data was compiled by JMM. In total, 18 geologic cross-sections of the Central Valley were created from an extensive analysis of available well logs, electric logs, oil and gas logs, hydrologic and geologic maps, and existing reports and cross-sections. The location of the cross-sections are shown in Fig. 3.2 and the individual geologic cross-sections are presented in Figs 3.3 a-r. The "?" mark on these figures stand for insufficient data. Additional data from USGS model (Williamson et al, 1985) were analyzed to obtain further information on the stratigraphy of the Central Valley. A thorough analysis of the geologic cross-sections and other geohydrologic information lead to the development of a three-layer groundwater model. Table 3.1 summarizes the geologic constituents of the model layers in both Sacramento and San Joaquin Valleys together with other hydrogeologic features.

TABLE 3.1

GEOLOGIC CHARACTERIZATION OF CENTRAL VALLEY GROUNDWATER BASIN

	Sacramento Valley				San Joaquin Valley			
Layer	Geologic Units	Base of Model Layer	Thickness	Additional Sources	Geologic Units	Base of Model Layer	Thickness	Additional Sources
1	Alluvium, Victor Formation, Red Bluff Formation, Fanglomerate, Fair Oaks Formation (mid-Pleistocene and younger)	Mid-Pleistocene Deposits	15-300 ft.	DWR (1974), DWR (1978)	Alluvium, Tulare Formation (Quarternary)	Top of Corcoran Clay	10-800 ft.	DWR Map (1981)
2	Laguna, Mehrten, Tehama, and Tuscan Formations (Pliocene and younger)	Base of Pumping Layer	50-1000 ft.	Williamson et al (1985)	Tulare, Kern River, and Mehrten Formations (Pliocene and younger)	Base of Pumping layer	15-1500 ft.	Williamson et al (1985)
3	Laguna, Tehama, and Mehrten Formations (Miocene and younger)	Base of Fresh Water	0-3800 ft.	Page, R.W. (1986)	Tulare, Kern River, and Mehrten Formations (Miocene and younger)	Base of Fresh Water	0-3800 ft.	Page, R.W. (1986)

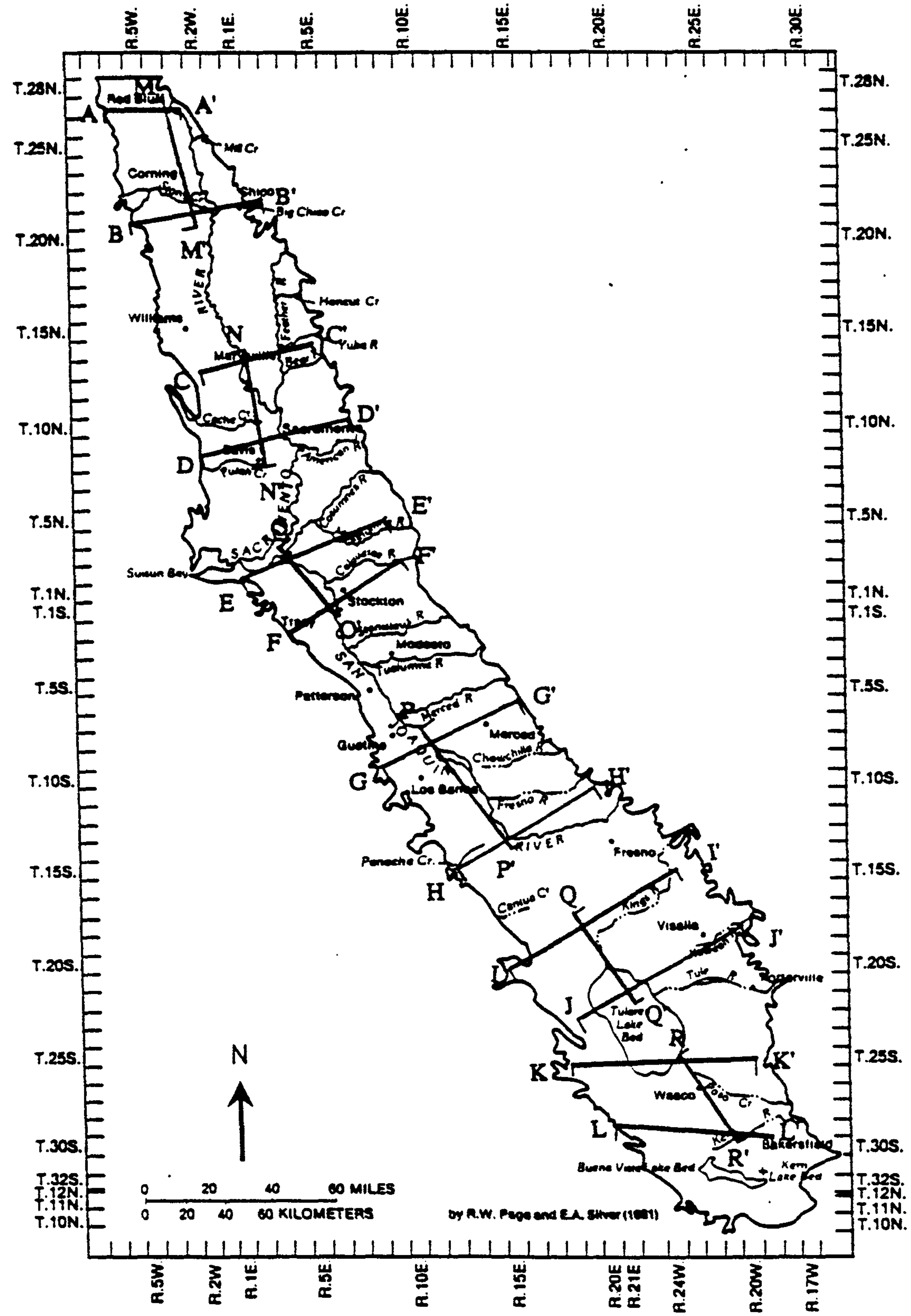

FIGURE 3.2

LOCATION OF CROSS-SECTIONS DEVELOPED BY JMM

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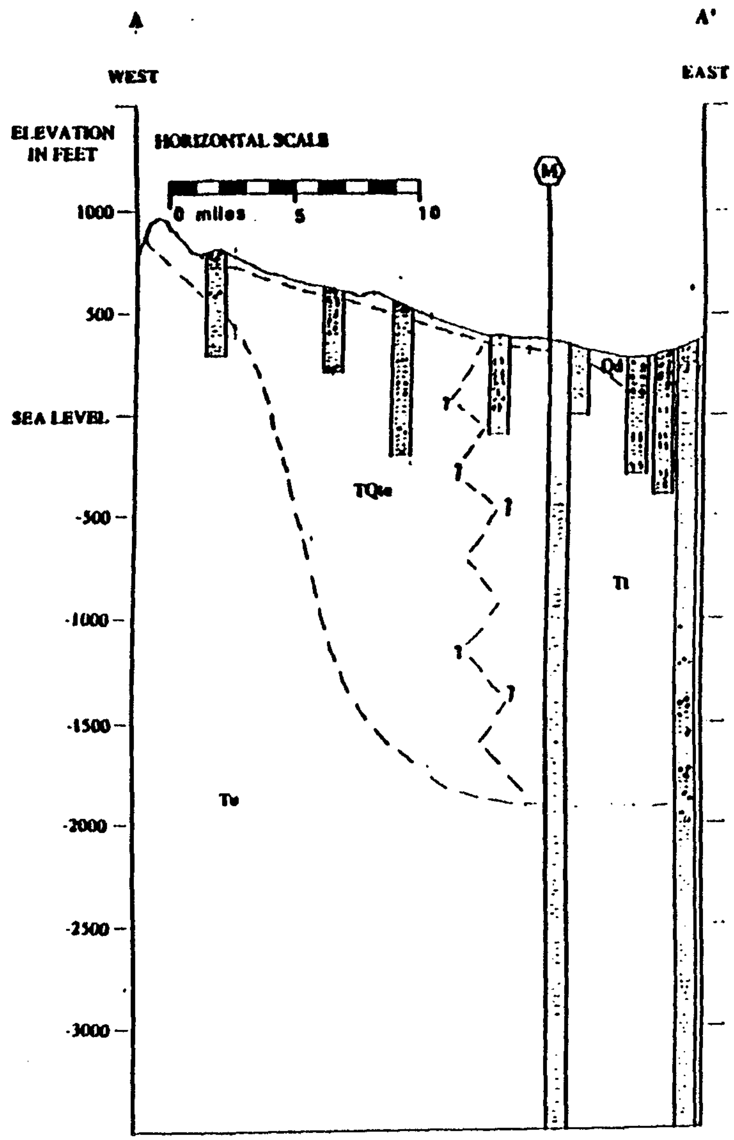
FIGURE 3.3(a)

CROSS-SECTION A - A'



LEGEND

Qd	QUATERNARY DEPOSITS
TQte	TEHAMA FORMATION
Tt	TUSCAN FORMATION
Tu	UNDIFFERENTIATED TERTIARY DEPOSITS
	SAND AND GRAVEL
	CLAY
	VOLCANIC ASH, LAVA, OR TUFF
	CONTACT BETWEEN UNITS (DASHED WHERE INFERRED)
B	INTERSECTING CROSS SECTIONS

FIGURE 3.3(b)

CROSS-SECTION B - B'

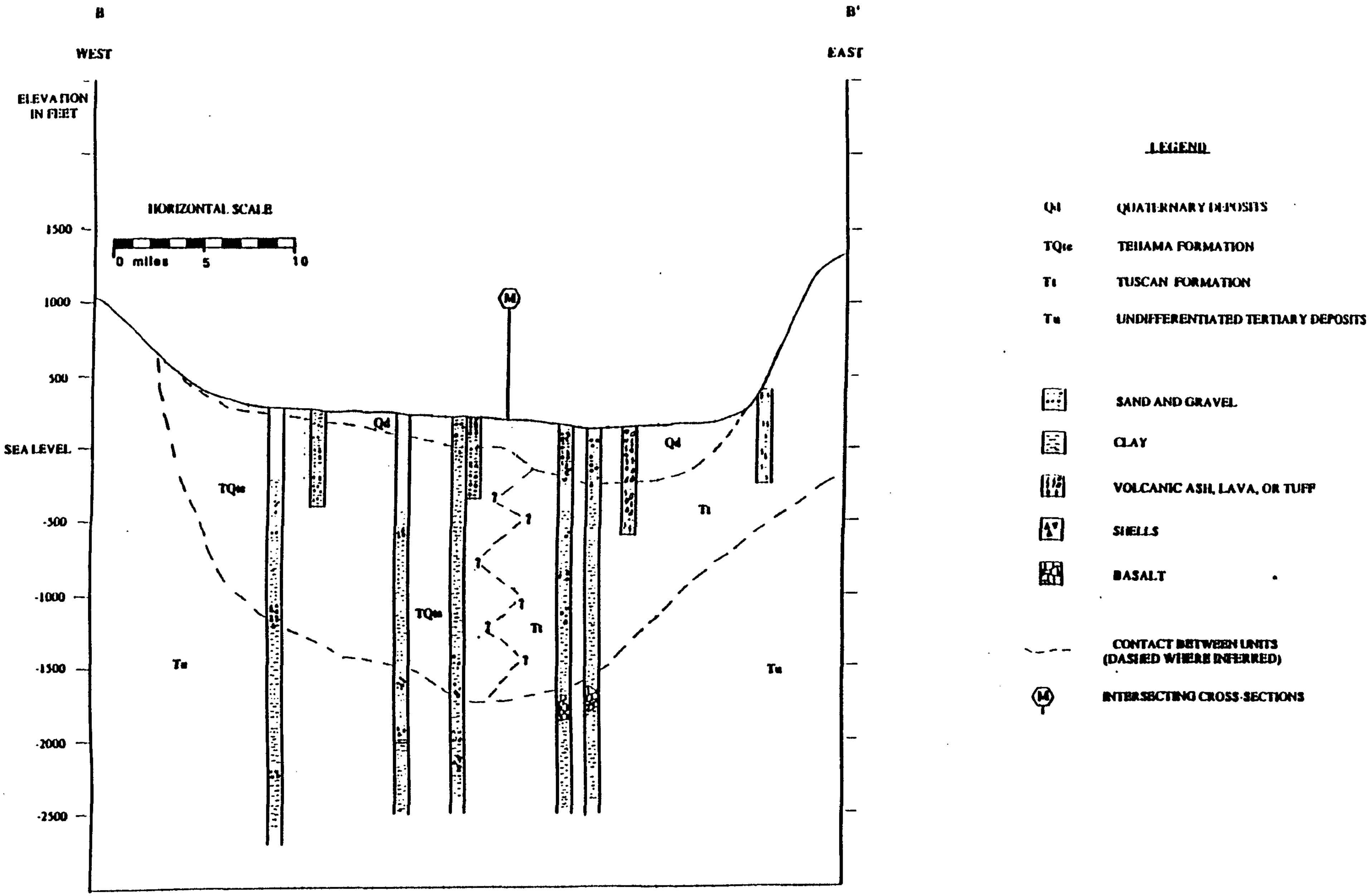


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FIGURE 3.3(c)

CROSS-SECTION C - C'

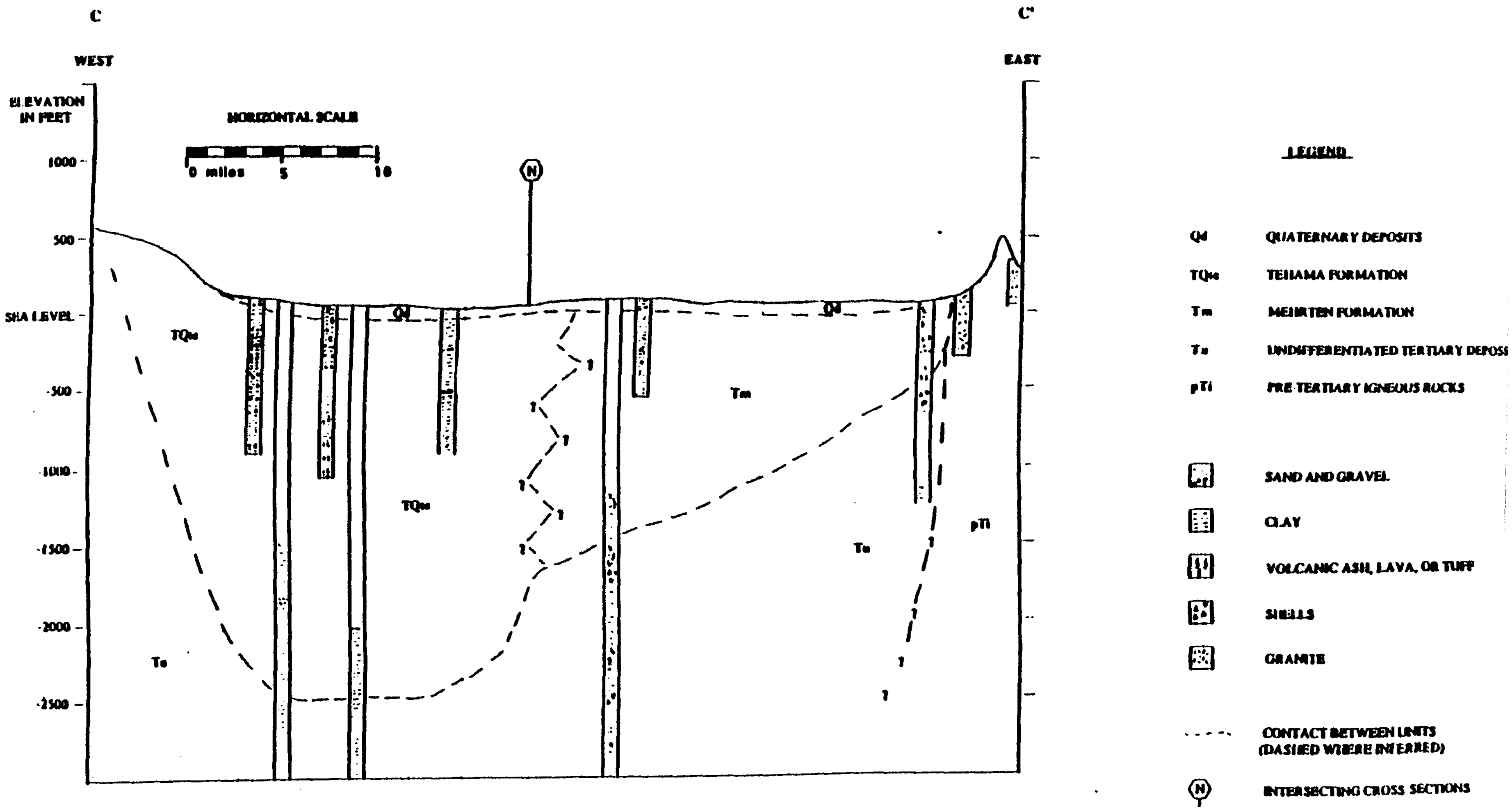

FIGURE 3.3(d)

CROSS-SECTION D - D'

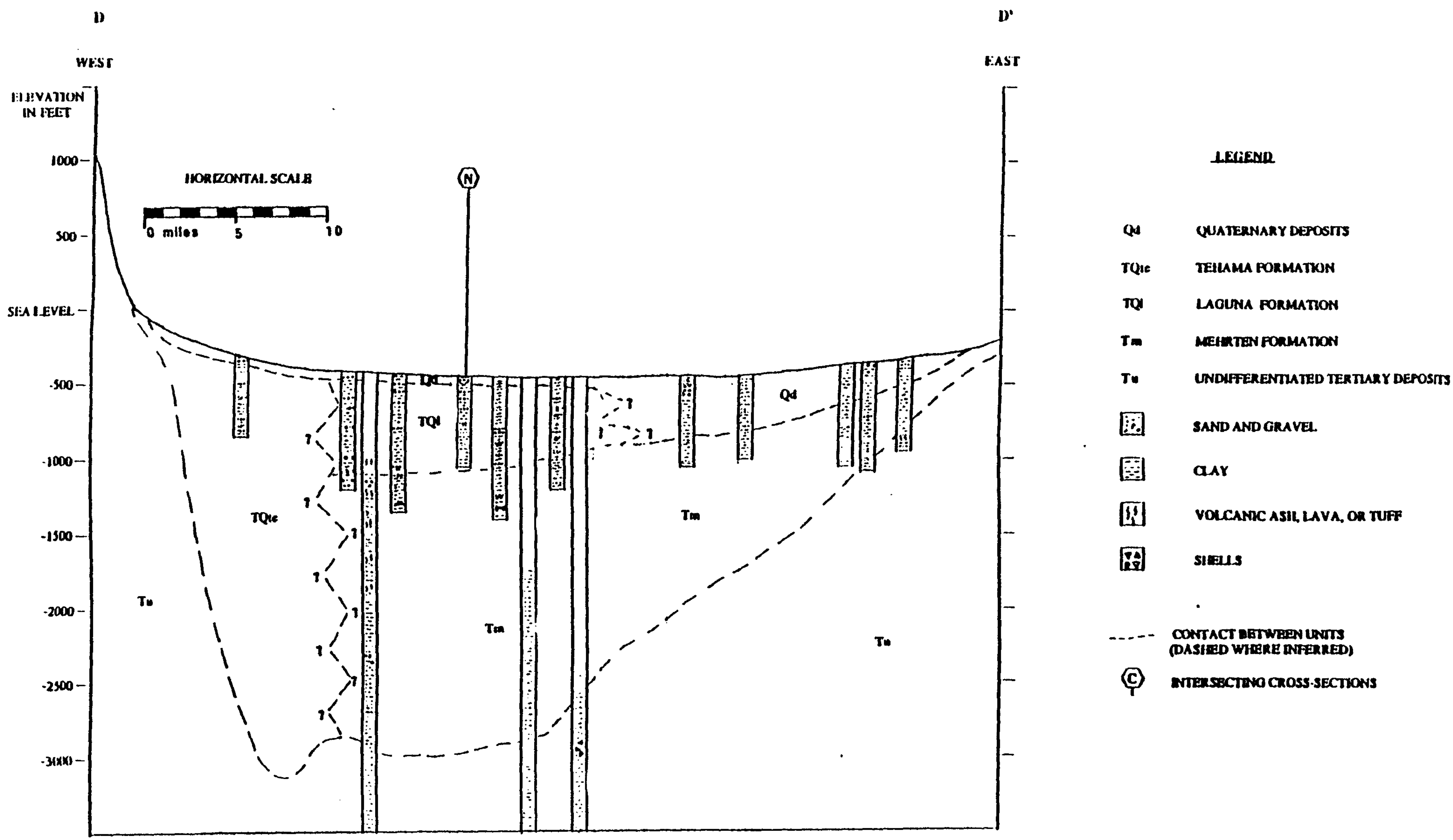

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FIGURE 3.3 (e)

CROSS-SECTION E - E'

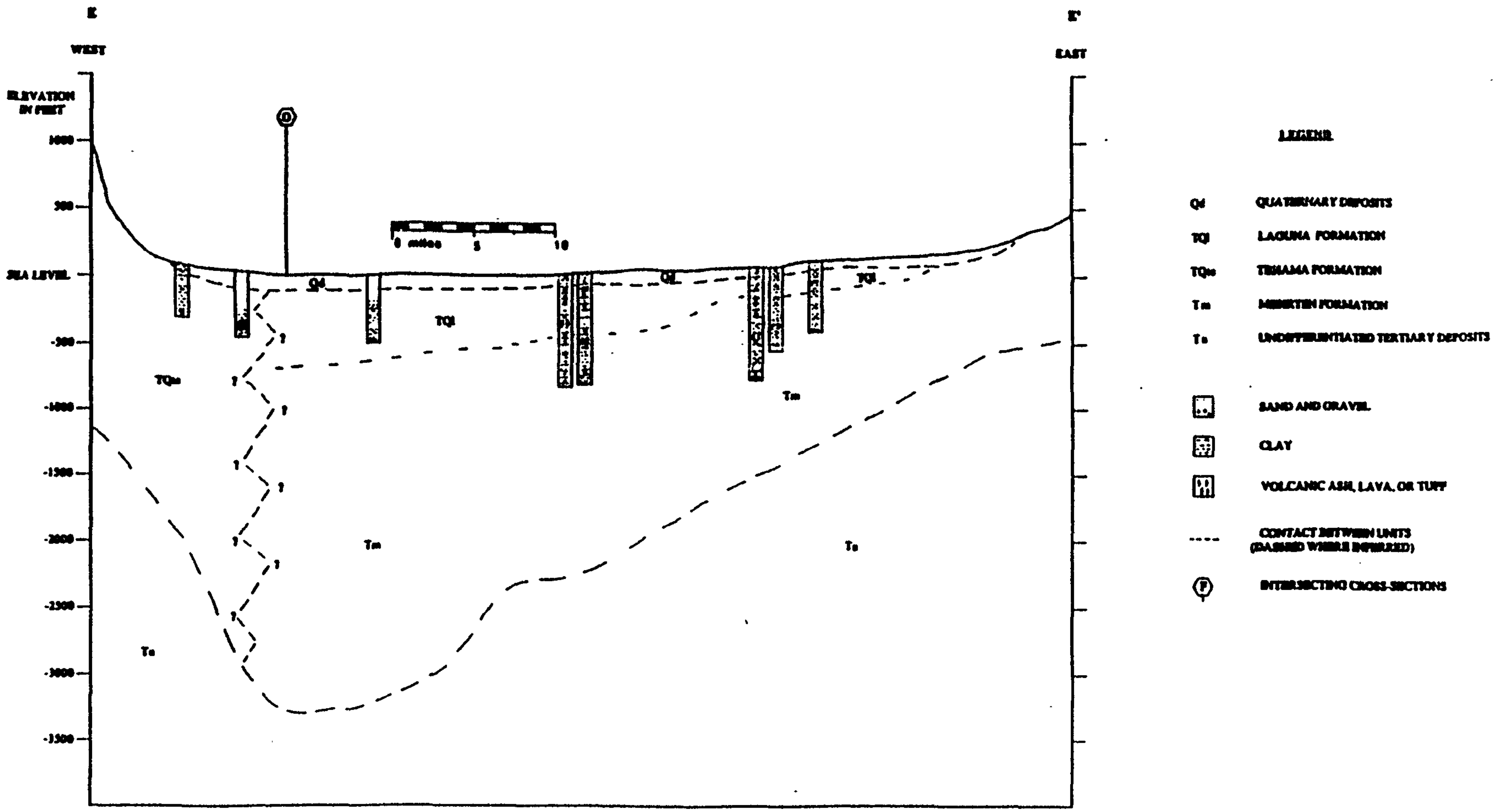

FIGURE 3.3 (f)

CROSS-SECTION F - F'

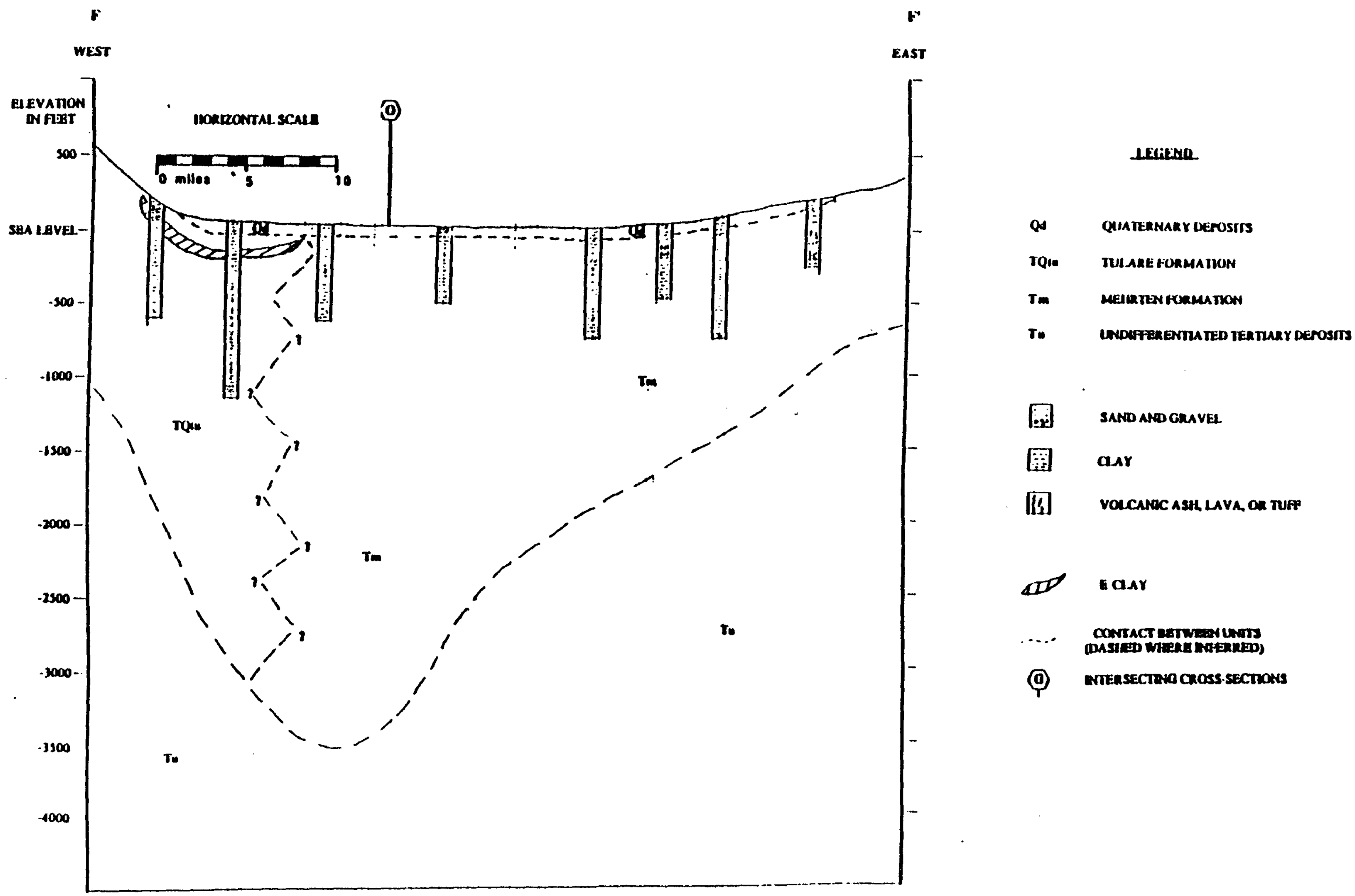

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FIGURE 3.3 (g)

CROSS-SECTION G - G'

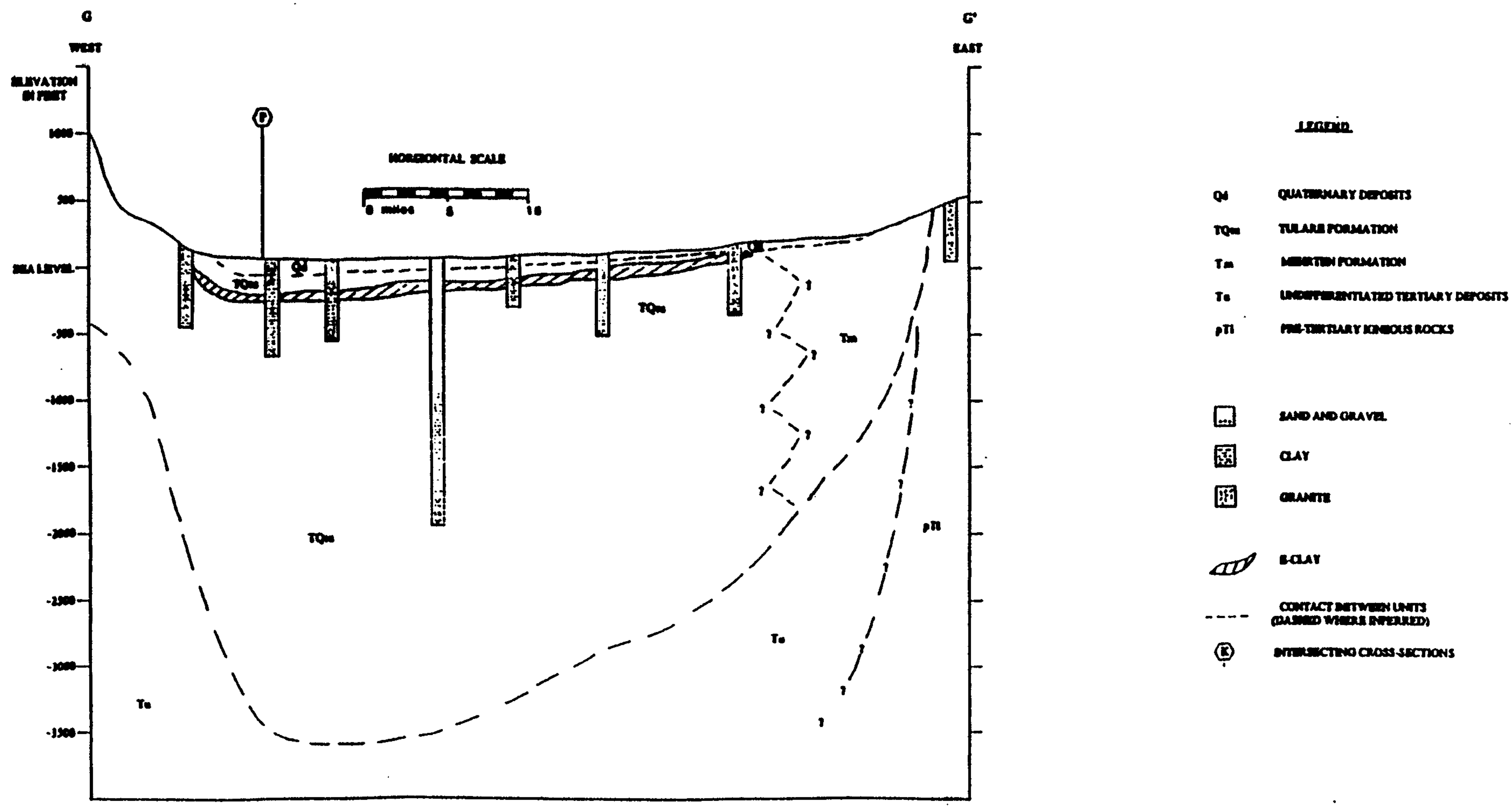

FIGURE 3.3 (h)

CROSS-SECTION H - H'

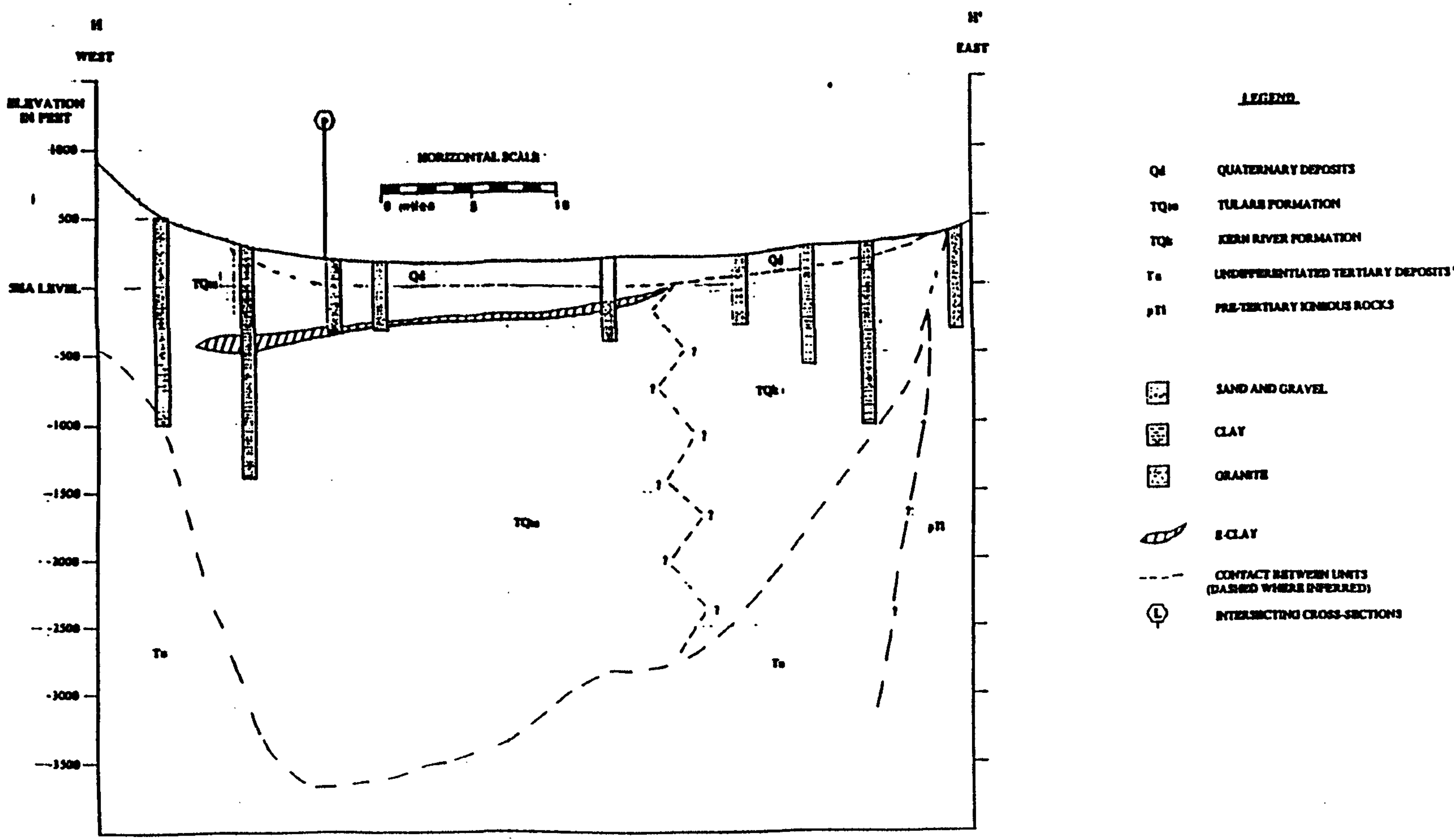

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FIGURE 3.3 (i)

CROSS- SECTION I - I'

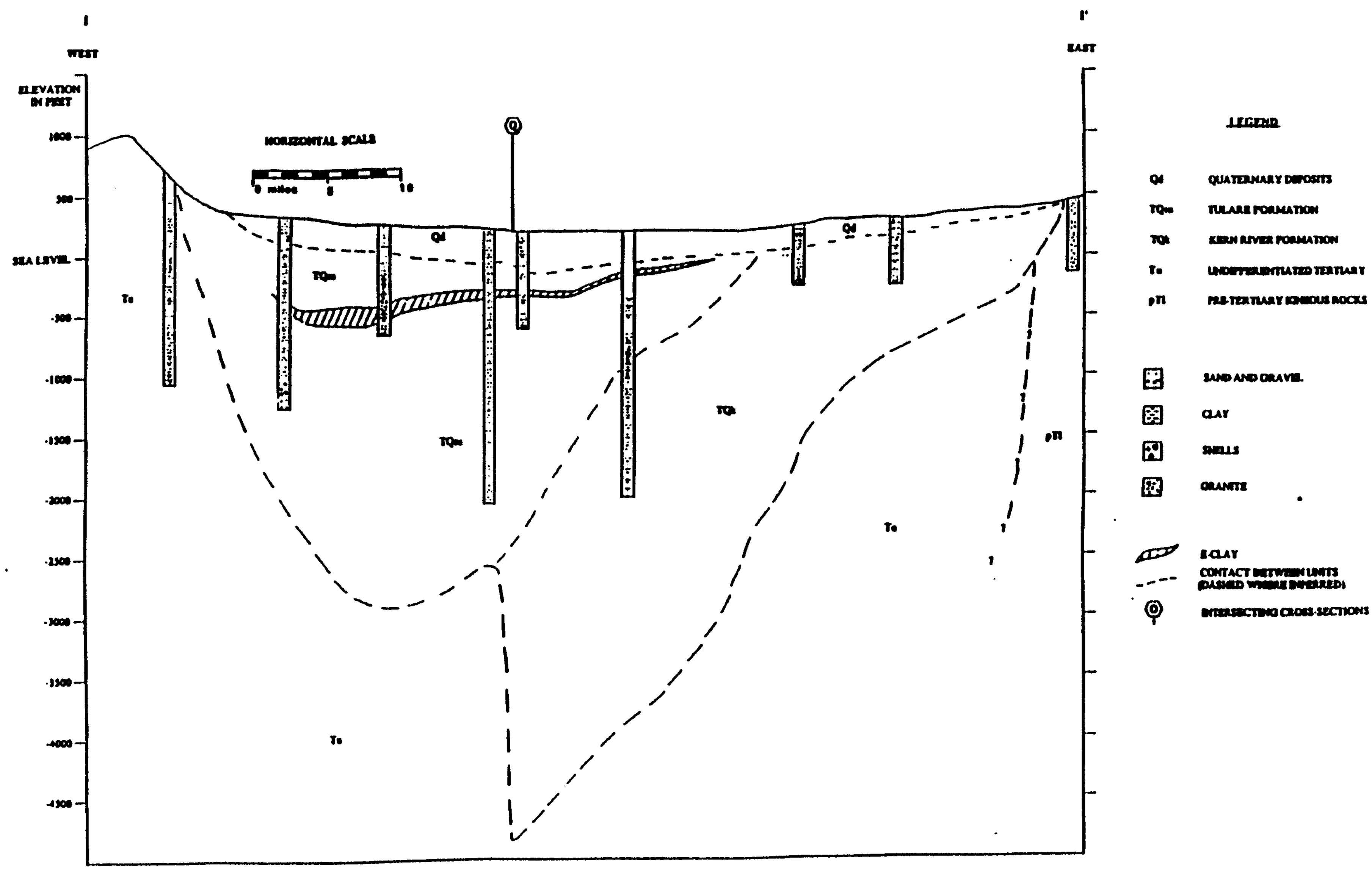

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FIGURE 3.3(j)

CROSS-SECTION J - J'

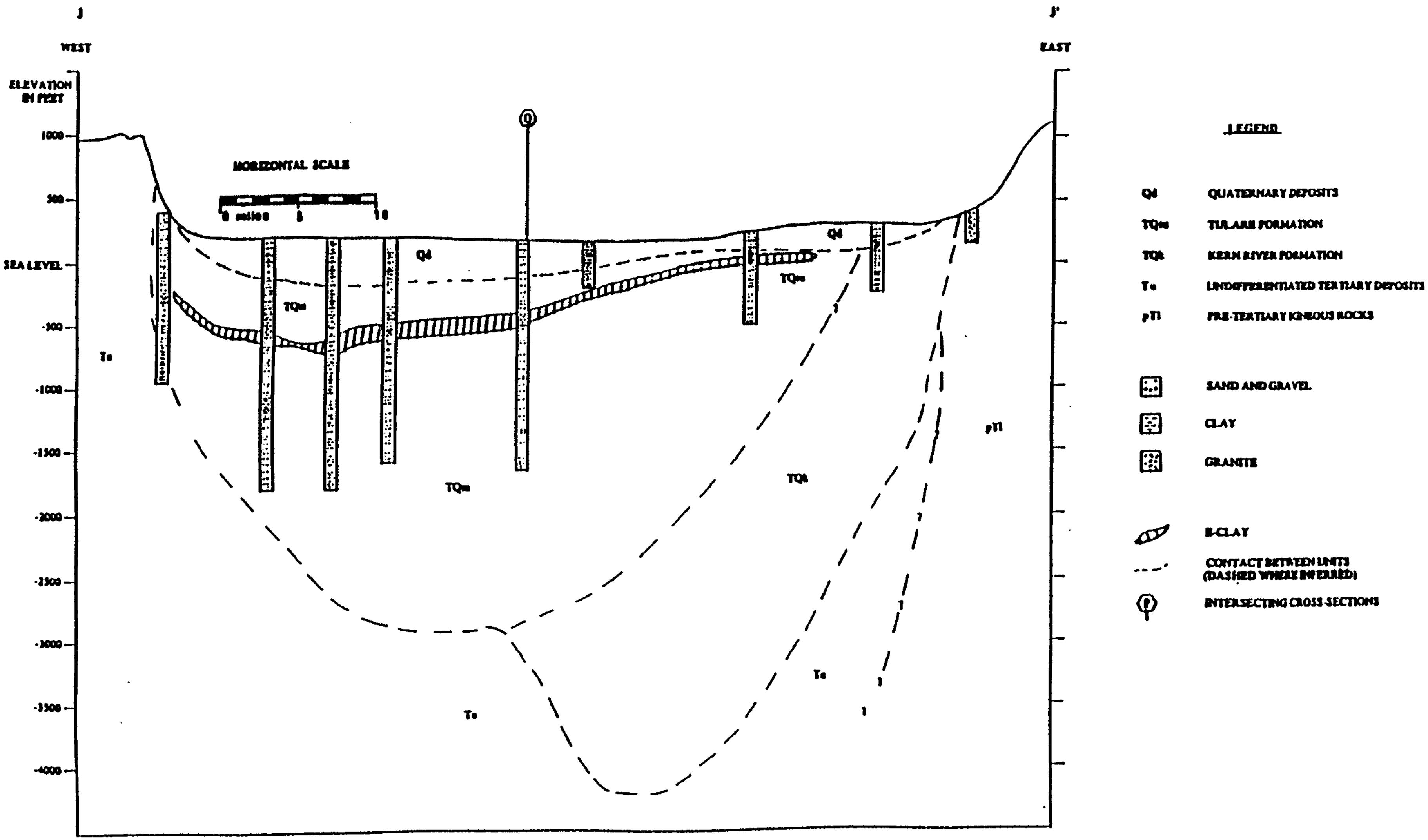

FIGURE 3.3(k)

CROSS-SECTION K - K'

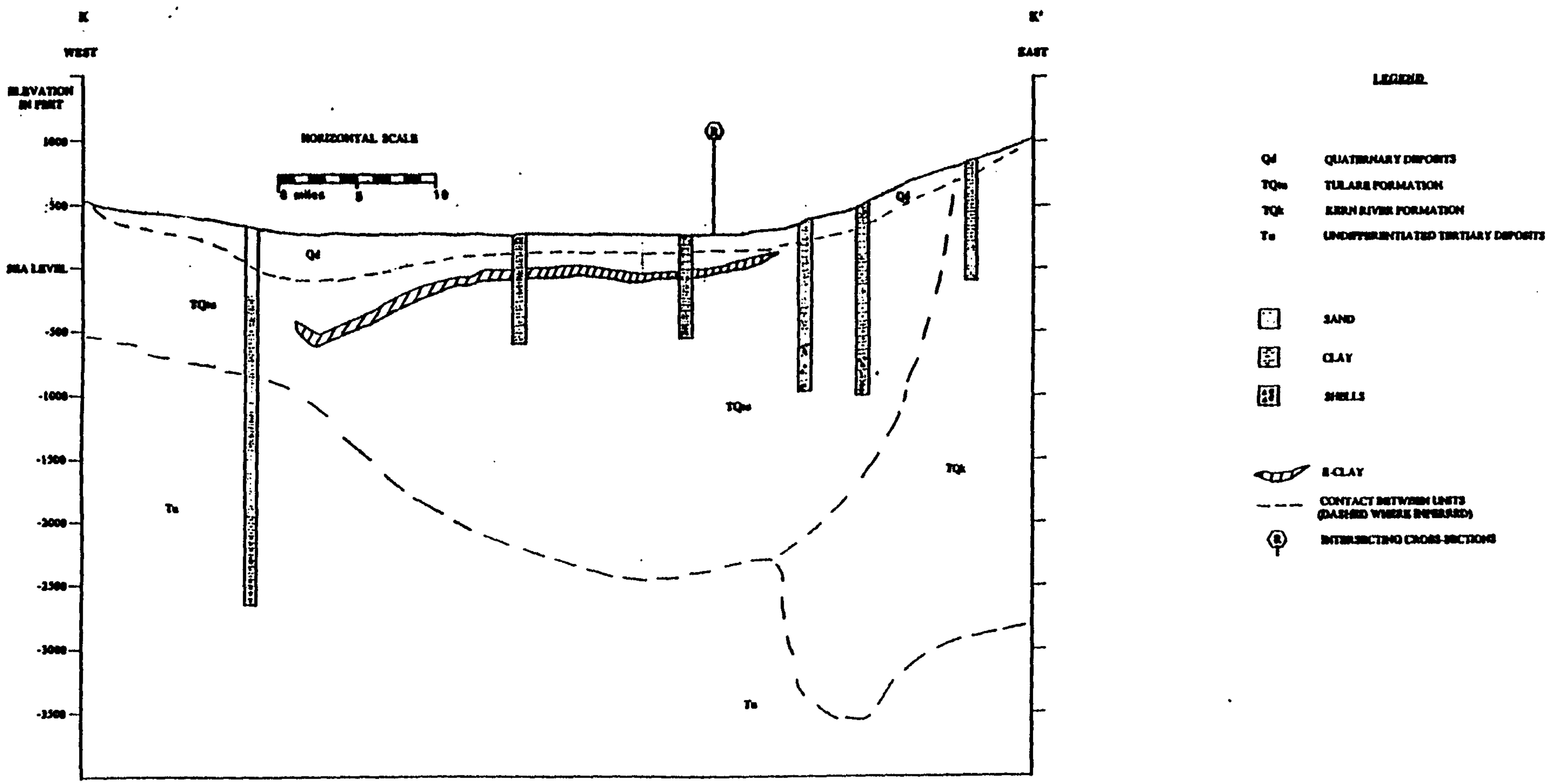

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FIGURE 3.3(l)

CROSS-SECTION L - L'

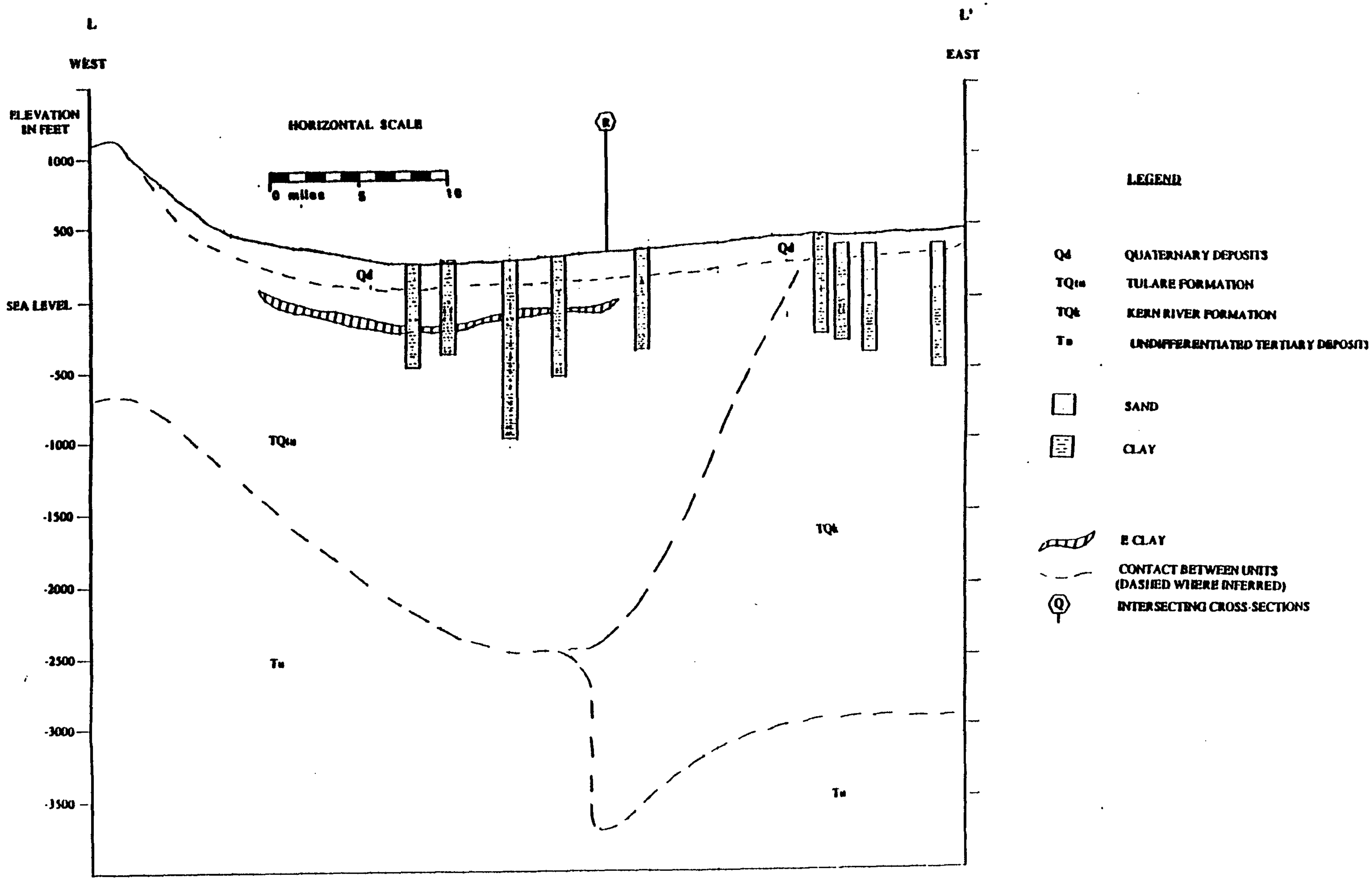

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FIGURE 3.3(m)

CROSS-SECTION M - M'

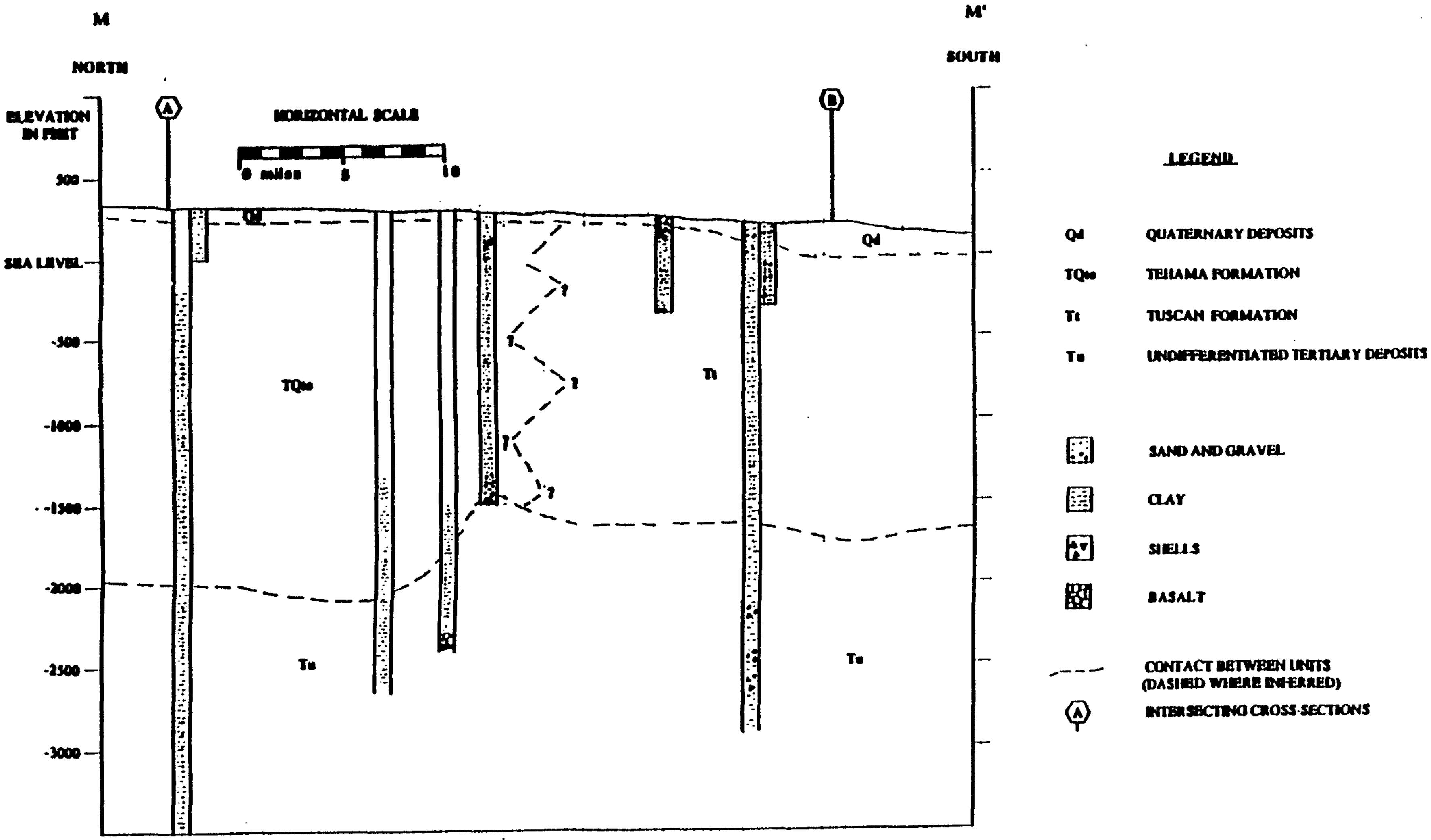

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FIGURE 3.3(n)

CROSS-SECTION N - N'

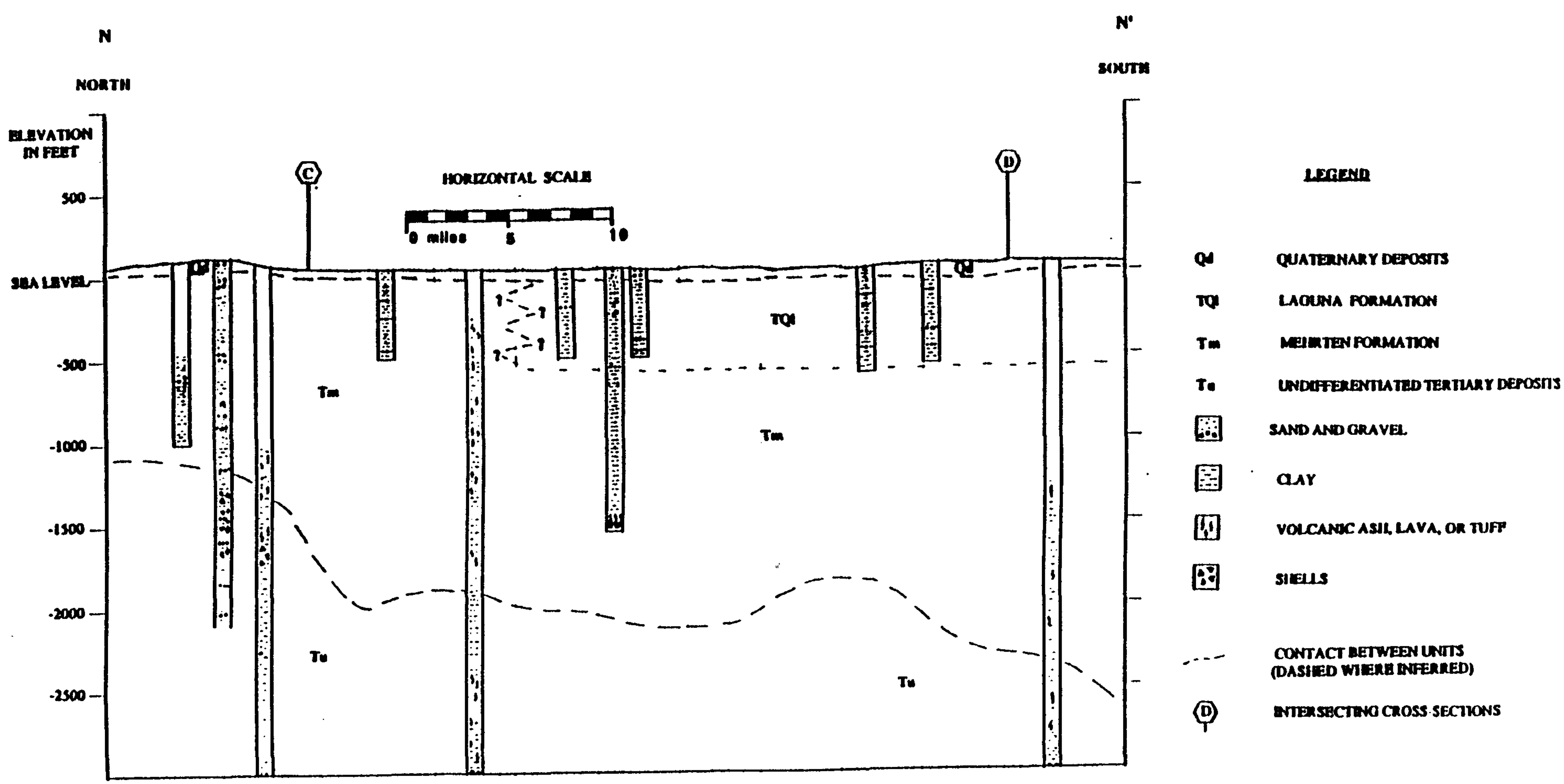

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FIGURE 3.3 (o)

CROSS-SECTION O - O'

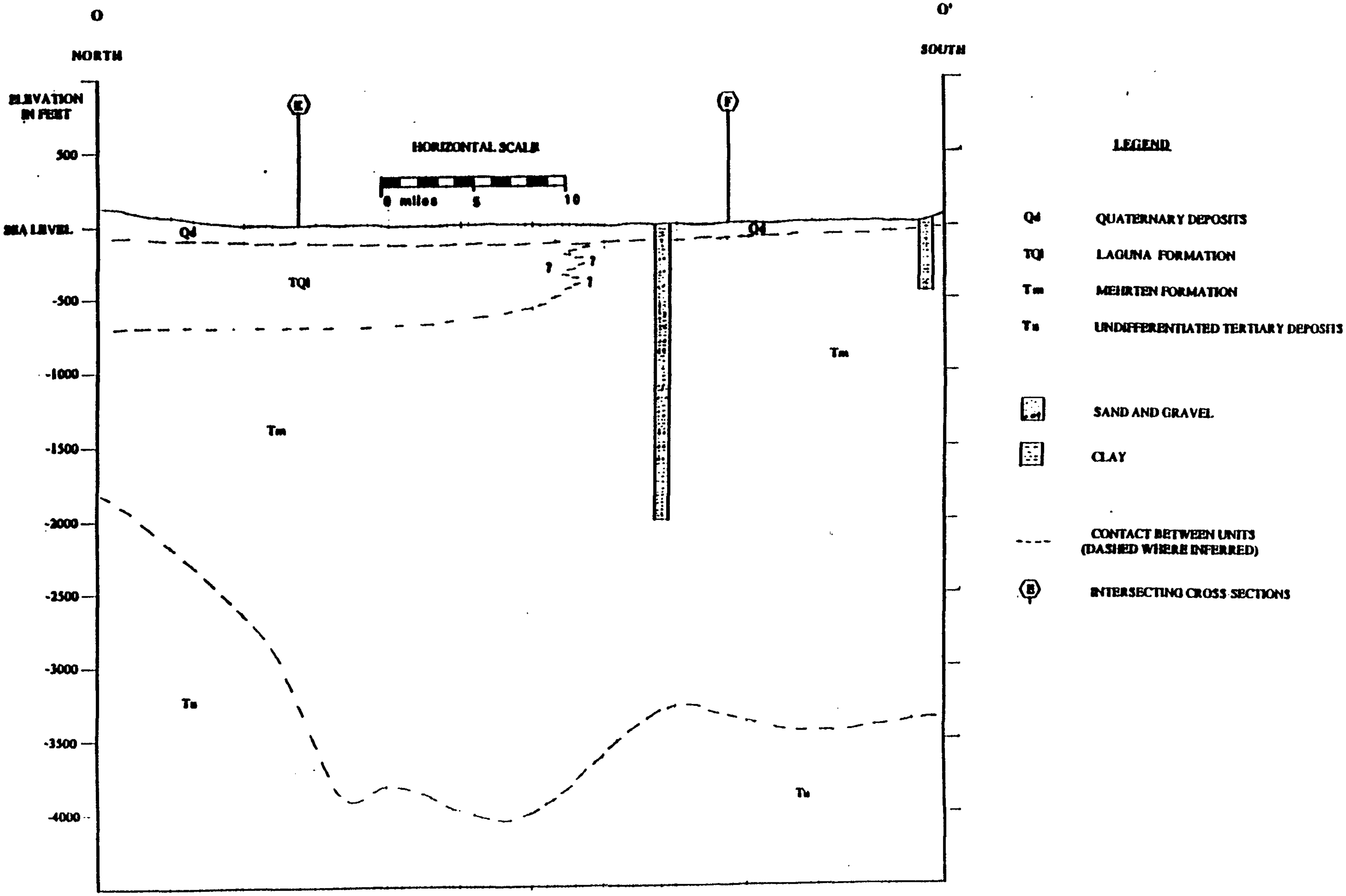

FIGURE 3.3 (p)

CROSS-SECTION P - P'

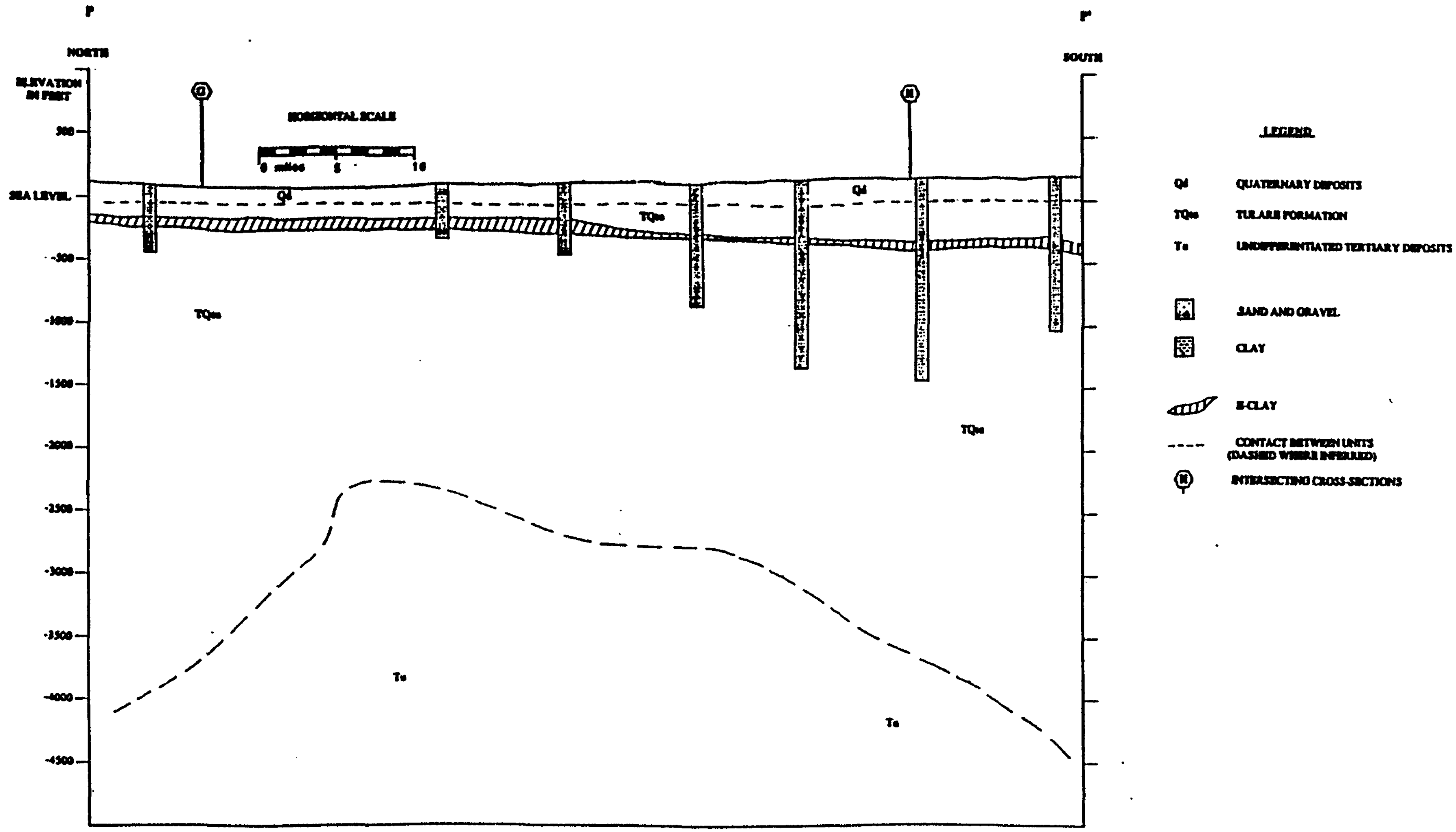

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FIGURE 3.3 (q)

CROSS-SECTION Q - Q'

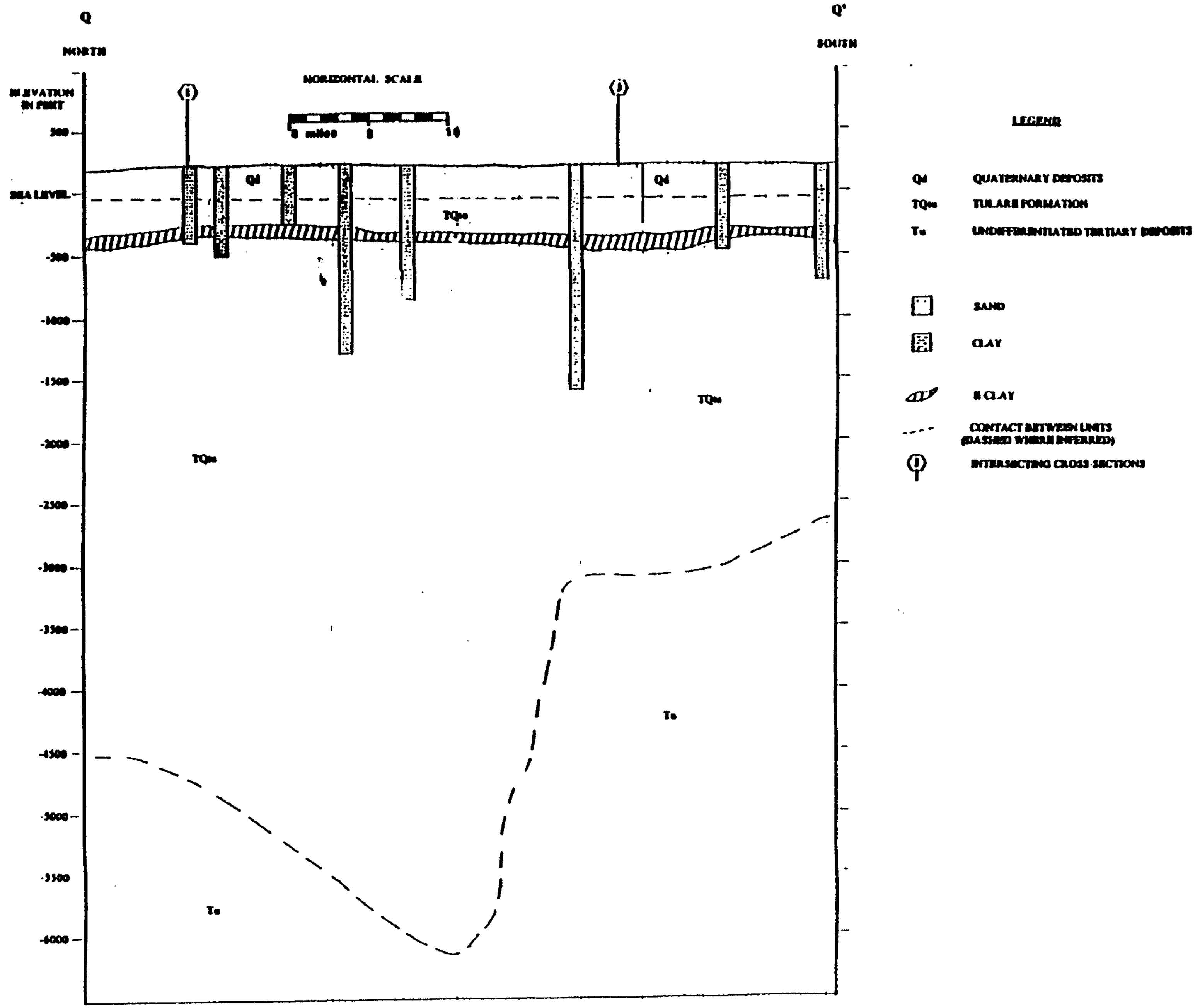

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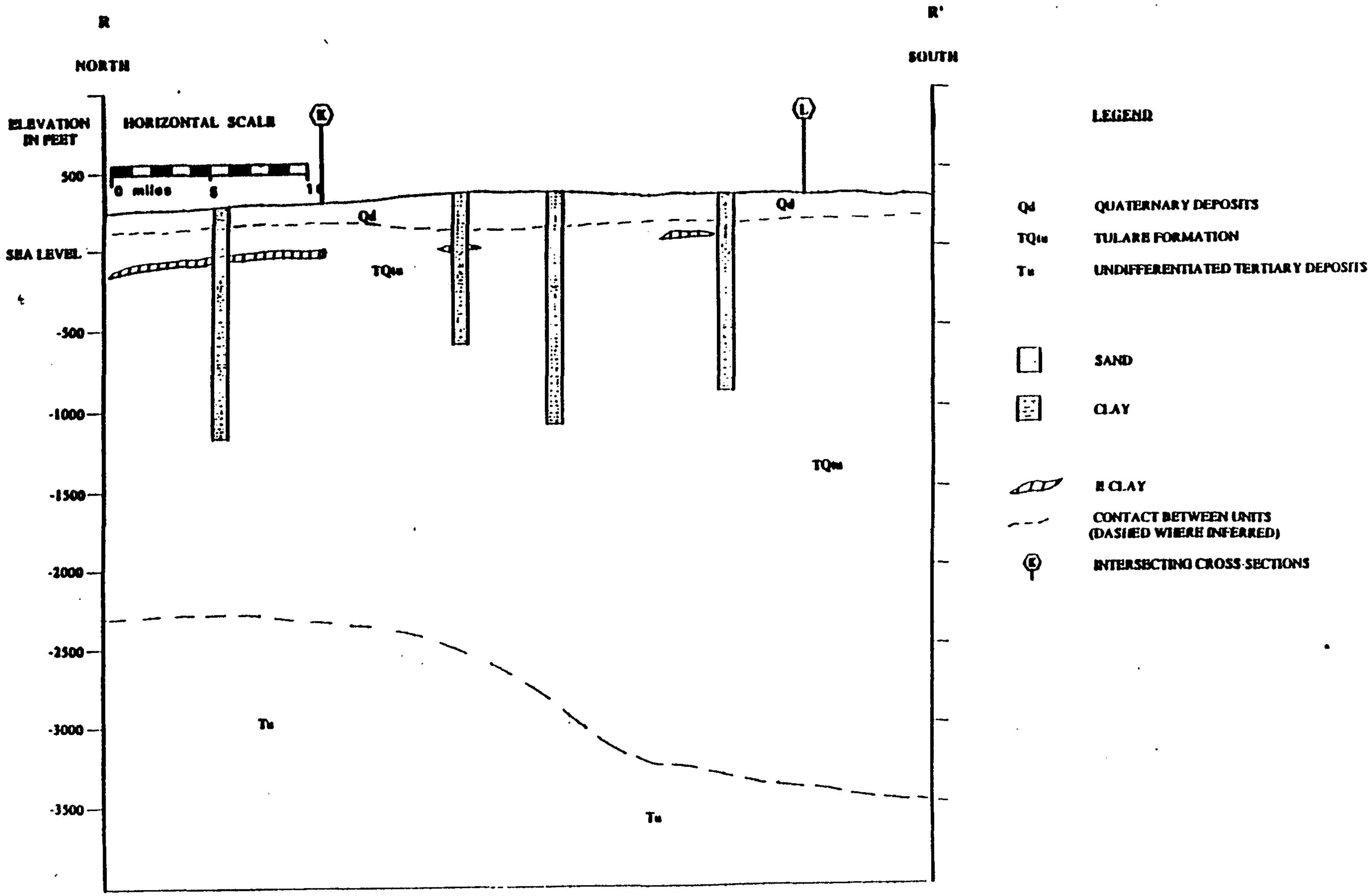
FIGURE 3.3 (r)

CROSS-SECTION R - R'



Drainage Pattern:

The surface water drainage pattern is determined by identifying the watershed boundaries and drainage direction from USGS topographic map for the State of California. For each element in the finite element grid, the available topographic information of the area is used to specify a stream node to which the surface runoff from the element tends to drain naturally.

Stream Cross-Sections:

Cross-section data at about 50 stream locations were obtained from the USGS for the purpose of streamflow modeling which is an integral component of the developed groundwater surface water model. The location of the measuring stations on the stream are shown in Fig. 3.4. From this database, the stream cross-section relationships were developed using the following equations:

$$Q = aD^b \tag{3.1}$$

$$W = rD^s \tag{3.2}$$

where

Q = discharge

D = depth of flow

W = wetted perimeter

and a, b, r, s are regression parameters.

The parameters a and b are obtained by plotting the Q vs. D on a logarithmic plotting paper. Application of Manning's equation gives:

$$s = b - 5/3$$

Parameter r is obtained by using the maximum depth and maximum width at the stream cross-section.

Those streams for which no USGS cross-sections can be readily obtained, the cross-sectional data from previous studies [State Water Resources Control Board (1987)] were used, when available. Those streams for which neither the USGS cross-section nor any other source of data was available, the cross-sectional data were developed by two methods: a) comparison with the cross-sectional data of a similar stream (similar average annual streamflow, geographic location etc.), and b) use Manning's equation with specified section (trapezoidal) and slopes ($z = 1:4$, $S_f = 0.005$)

The sources of stream cross-section data for each modeled stream are given in Table 3.2.

3.2 HYDROLOGY/CLIMATOLOGY

Streamflow:

The mean annual streamflow entering the Central Valley around its perimeter is about 31.7 million acre-ft and its mere volume underscores the importance of the streamflow in the region's overall water supply. Most of the perennial streams enter the Valley from Sierra Nevada in the east, and from Klamath mountains and Cascade Ranges on the north. Except for some streams in the northwest, no perennial streams of substantial flow enters the Valley from the west. Hence, the streamflow in the Central Valley is entirely dependent on the precipitation in the Sierra Nevada and the Klamath mountains. There is a time delay between the precipitation and runoff. The snowpack melts in the summer months when there is virtually no precipitation. As such, about 78 percent of the total unimpaired runoff to the valley occurs in the six months between January and June, while the most of the precipitation takes place in winter months from November through March.

For the purpose of this model, 38 stream inflows entering the model boundary were included. In addition, 4 internal drainage canals/bypasses were also modeled. A list of the streams and their data sources is given in Table 3.2. For some streams, a single gaging station near the boundary of the model area did not provide the streamflow data for the entire study period. As such, a combination of stations are used to cover the entire period or the missing data is estimated by correlating with the data of a neighboring station on the same stream for which a longer period of data exists. All the stream gaging stations that are used in compiling the streamflow data for this model are shown in Fig. 3.4. As listed in Table 3.2, most of the stream inflow data comes from the DWR's Depletion Model database. Two data sets - American River inflow and Feather River inflow - were revised based on the discussion with DWR's staff members. The American River inflow data used in the model is the American River flow at Fair Oaks gage plus the Historic Export Folsom South Canal to DSA 59 (DWR, 1990a). The Feather River inflow data used in the model is the sum of historic outflow Feather River below Oroville Lake and the Kelly Ridge return flow to Feather River (DWR, 1990a). The Sacramento River flow at Keswick prior to 1939 was estimated by corelating with the Sacramento River flow at Shasta Dam as

TABLE 3.2 A

SOURCES OF STREAM DATA IN SACRAMENTO VALLEY

	STREAM INFLOW		STREAM CROSS-SECTIONS	
Stream Name	Gaging Station[1/]	Source	Location [3/]	Source[2,3/]
Sacramento River	at Keswick	USGS	at Bend Bridge	USGS
			at Butte City	
			at Colusa	
			at Wilkens Slough	
			at Vernon	
Cow Creek	near Milville	USGS	near Milville	USGS
Battle Creek	below Coleman Fish Hatchery	USGS		Estimated
Cottonwood Creek	near Cottonwood	USGS		Estimated
Paynes Creek		Depletion Model		Estimated
Antelope Creek	near Red Bluff	Depletion Model		Estimated
Mill Creek	near Los Molinos	Depletion Model	near Los Molinos	USGS
Elder Creek	at Paskenta	Depletion Model	near Paskenta	USGS
Thomas Creek	at Paskenta	Depletion Model	at Paskenta	USGS
Deer Creek	near Vina/Red Bluff	Depletion Model	near Vina	USGS
Stony Creek	near Fruto	Depletion Model	near Black Butte Dam	USGS
Big Chico Creek	near Chico	Depletion Model	Estimated	USGS
Butte and Chico Creeks	near Chico	Depletion Model	near Chico	USGS
Glenn-Colusa Canal	diversion from Sacramento River	Depletion Model		previous study
Colusa Basin Drain	not applicable	Simulated		previous study
Feather River	below Oroville Dam	Depletion Model	near Gridley	USGS
Sutter Bypass	Tisdale Weir	DWR		previous study
Yuba River	Below Englebright Dam	Depletion Model	near Marysville	USGS
Bear River	at Camp Far West Dam	Depletion Model	near Wheatland	USGS
Cache Creek	above Rumsey	Depletion Model	at Yolo	USGS
American River	below Folsom Lake	Depletion Model	at Fair Oaks	USGS
Yolo Bypass	Freemont and Sacramento Weirs	DWR	near Woodland	previous study
Putah Creek	above Winters	Depletion Model	near Winters	USGS
Cosumnes River	at Michigan Bar	Depletion Model	at Michigan Bar	USGS
Dry Creek	near Ione	Depletion Model		previous study
Mokelumne River	below Camanche Reservoir	Depletion Model	near Camanche Dam at Woodbridge	USGS
Calaveras River	at Jenny Lind	Depletion Model	below New Hogan Dam	USGS

1/ Only the station with the longest period of record mentioned. Missing periods of data are estimated from neighboring gaging stations. See the source for details.

2/ Estimated - see text.

3/ Previous Study - Central Valley Groundwater Simulation Model (Boyle, 1987).

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TABLE 3.2 B

SOURCES OF STREAM DATA IN SAN JOAQUIN VALLEY

	STREAM INFLOW		STREAM CROSS-SECTIONS	
Stream Name	Gaging Station[1/]	Source[3/]	Location	Source[2,3/]
Stanislaus River	below New Melones Dam	Depletion Model	below Goodwin Dam at Ripon	USGS
Tuolumne River	above La Grange Dam	Depletion Model	below La Grange Dam at Modesto	USGS
Orestimba Creek	near Newman	USGS	near Newman	USGS
Merced River	at Exchequer Dam	Depletion Model	below Merced Falls Dam at Shaffer Bridge near Cressey near Stevinson	USGS
Bear Creek	near Catheys	Depletion Model		previous study
Deadman's Creek	based on Bear Creek near Catheys	Previous Study		previous study
Chowchilla River	at Buchanon Damsite near Raymond	Depletion Model	below Buchanon Dam	USGS
Fresno River	at Knowles	Depletion Model	below Hidden Dam near Daulton	USGS
Berenda Creek	coorelation with Fresno River at Knowles	Depletion Model		previous study
San Joaquin River	below Friant Dam	Depletion Model	below Friant Dam near Newman at Vernalis	USGS
Fresno Slough	near San Joaquin	Depletion Model		previous study
Kings River	at Piedra	USGS	below Pine Flat Dam	USGS
Kaweah River	near Three Rivers	USGS	below Terminus Dam	USGS
Tule River	near Porterville	USGS	below Success Dam	USGS
Kern River	near Bakersfield	USGS	below Isabella Dam	USGS

1/ Only the station with the longest period of record mentioned. Missing periods of data are estimated from neighboring gaging stations. See the source for details.

2/ Estimated - see text.

3/ Previous Study - Central Valley Groundwater Simulation Model (Boyle, 1987).

provided in the Depletion Model database. For Cow Creek, Battle Creek and Cottonwood Creek, the streamflow data is available for period after 1940. The missing data was estimated by undertaking an annual water balance approach using the stramflow data of Sacramento River at Keswick at Red Bluff, surface water diverisons of Sacramento River from Keswick to Red Bluff, and taking account of the unmeasured accretions. The monthly distribution of estimated annual flow was determined from the recorded monthly flow pattern of the corresponding stream. For Deadman's Creek, no gaged streamflow data could be found and thus the historic outflow of DSA 42 is divided equally into two inflows - Bear Creek and Deadman's Creek as was done in a previous study (Boyle, 1987). Fresno River inflow represents the sum of Fresno river flow at Knowles and Berenda Creek inflow obtained from the Depletion Model database.

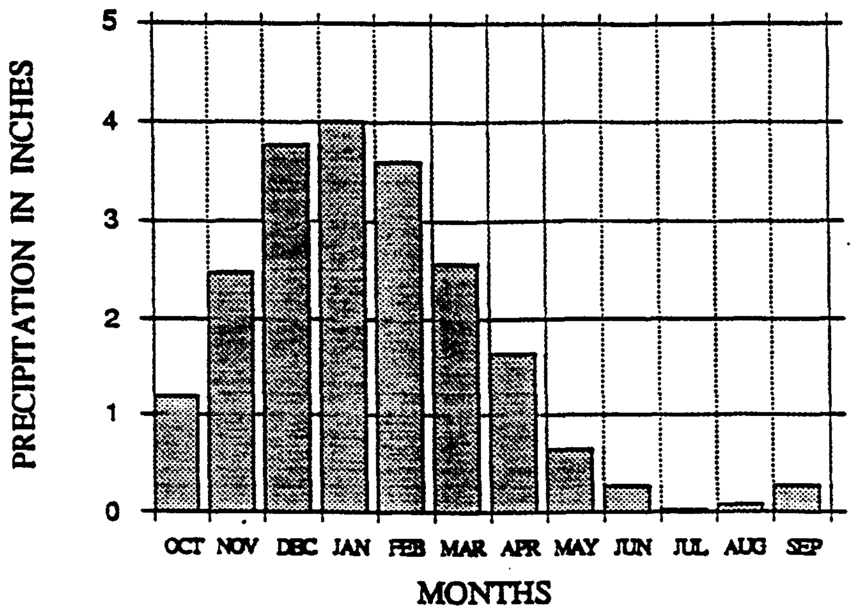
There are several smaller streams along the perimeter of the valley which were not modeled. However, their contributions to the surface runoff and baseflow were included in the model in an indirect manner by specifying the following for each small watershed: (i) the drainage area, (ii) the stream node to which it drains to, (iii) the groundwater node for baseflow recharge, and (iv) the appropriate rainfall station and a rainfall factor to account for the higher altitude along the valley boundary. These streams generate little runoff in most of the years. However, they were included because, on an aggregate basis, they are an important source of recharge as most runoff, whenever it occurs, percolates to the groundwater basin.

Rainfall:

The moist air masses that are swept inland from the Pacific provide most of the rainfall in the Central Valley. The overall climate is of Mediterranean type (dry summers). Nearly all the precipitation occurs in the five winter months - November through March -with practically nothing during the summer growing seasons as depicted in Fig. 3.5. Average annual precipitation in the Sacramento Valley ranges from about 26 inches in the flanks to 14 inches near the Sutter Buttes (Rantz, 1969), while in the San Joaquin Valley it ranges from about 15 inches along the eastern flanks of the valley to about 5 inches near Bakersfield. The driest part of the Central Valley is Tulare Lake basin where the mean annual precipitation ranges from 5 to 9 inches.

The rainfall data that are used in the model were obtained from DWR and the National Oceanic and Atmospheric Administration (NOAA). For model subregions 1 through 9, a single set of rainfall data was used for each subregion as obtained from the Consumptive Use model of DWR (1979). These single sets of data were prepared by DWR from a weighted average of several rainfall gaging stations within the corresponding DSA. For model subregions 10 through 21, readily available data from NOAA was used. A total of 8 gaging stations, as shown in Fig. 3.4, was selected and their areas of influence were obtained by the

SACRAMENTO VALLEY : 1922-80 MEAN RAINFALL



SAN JOAQUIN VALLEY : 1922-80 MEAN RAINFALL

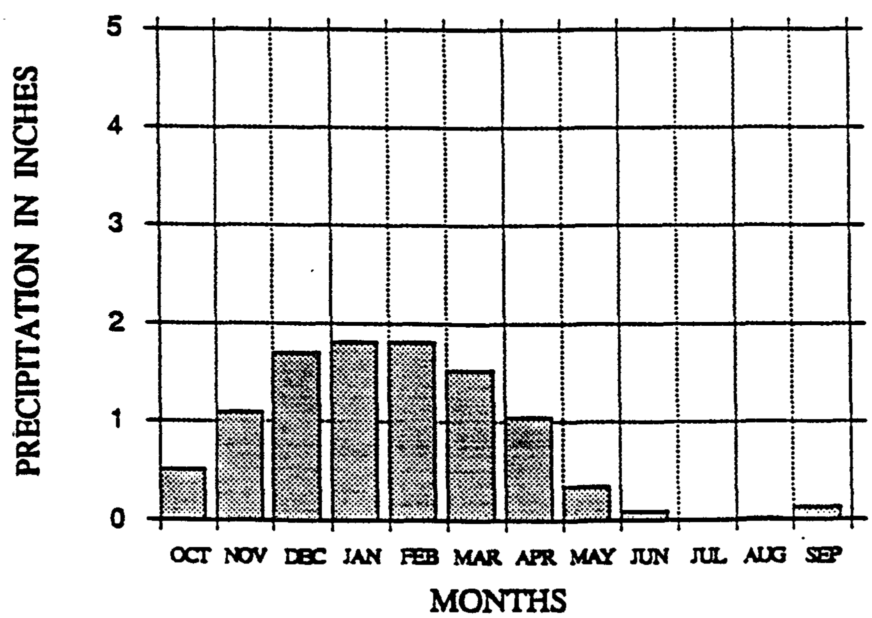


FIGURE 3.5

HISTORIC MEAN RAINFALL

Thiessen polygon method. The detailed spatial variation of rainfall was achieved by determining a weighting factor for each element corresponding to the rainfall data set the element is associated with. This required specifying two items for each element in the model grid: a) the rainfall data set to which the element is associated with and b) a weighing factor for the element, which is determined by the following formula:

$$\text{weighting factor} = \frac{\text{long term mean annual precipitation at the element}}{\text{long term average annual precipitation at associated station}}$$

The long term mean annual rainfall of the element was obtained from the isohyetal map of mean annual precipitation for the State of California (Rantz, 1969).

Table 3.3 summarizes the 17 rainfall data sets and the associated gaging stations.

Hydrologic Soil Group:

The hydrologic properties of the soil are very important in the groundwater and surface water modeling. According to the Soil Conservation Service's (SCS) definition, when runoff from individual storms is the major concern, the soil properties can be represented by a hydrologic parameter, "the minimum rate of infiltration for a bare soil after prolonged wetting". The influences of both the surface and the horizons of soil are thereby included. Watershed soils can be classified into four major groups on the basis of hydrologic properties, independent of watershed slope and cover. These hydrologic soil groups are:

Group A (low runoff potential) - mainly sands and gravel that are deep and well to excessively drained; shows high transmissivity.

Group B (low to moderate runoff potential) - soils of moderately fine to moderately coarse textures, moderately deep and drained; shows medium transmissivity.

Group C (moderate to high runoff potential) - soils of moderately fine to fine texture, with an impeding clay layer; shows low transmissivity.

Group D (high runoff potential) - mainly clay soils with a high swelling potential, shallow soils over nearly impervious materials and soils with high permanent water table; shows poor transmissivity.

When soils of an area are divided into these groups, the runoff curve number is derived for each subarea and is used in estimating infiltration and runoff, following the guidelines and tables given in the National Engineering Handbook -

TABLE 3.3

PRECIPITATION DATA SOURCES

Data Set	Associated Gaging Stations
1	Two stations average for DSA 58 (Redding and Extended Red Bluff)
2	Two stations average for DSA 10 (Orland and Extended Red Bluff)
3	Three stations average for DSA 12 (Colusa, Extended Knights Landing, and Willows)
4	Three stations average for DSA 15 (Colusa, Extended Knights Landing, and Willows)
5	Three stations average for DSA 69 (Colusa, Chico, and Marysville)
6	Three stations average for DSA 65 (Davis, Woodland, and Vacaville)
7	Two stations average for DSA 70 (Knights Landing and Rocklin)
8	Three stations average for DSA 50 (Galt, Lodi, and Oakdale)
9	Seven Stations average for DSA 55 (Brentwood, Davis, Galt, Lodi, Rio Vista, Stockton, Tracy)
10	Modesto
11	Merced Fire Station #2
12	Los Banos
13	Madera
14	Friant Government Camp
15	Fresno
16	Hanford
17	Bakersfield

4 (SCS, 1985). The Central Valley soil was classified into these groups by using numerous county soil reports from Soil Conservation Service and other studies and reports on the Central Valley soils. The composite hydrologic soil group map for the entire study area is shown in Fig. 3.5. In most areas, the SCS soil surveys were comprehensive and were directly used in developing this soil map. However, in some areas the soil surveys were incomplete, in progress, or unavailable. In those areas, the hydrologic soil characteristics were estimated based on the available information for the corresponding area and the vicinity Those areas are Butte County, Stanislaus County (west side), Tulare County (west side), Kern County (north-east and south-west portions), and are identified by question mark "?" on Fig 3.6. Using this composite map, the hydrologic soil characteristics was specified for each finite element of the model. In this process, it was recognized that an element may well belong to more than one soil group depending on its spatial extent. To incorporate this within element variability, a soil group factor was assigned to each element to better represent the soil characteristics of the element. The soil factor is computed by the formula given below:

$$\text{Soil factor} = \frac{1}{A}\sum_{i=1}^{4} A_i * S_i \qquad (3.3)$$

where

$A =$ total area of the element

$A_i =$ area of the element that belongs to soil group i

$i =$ 1 for group A; 2 for group B; 3 for group C; and 4 for group D

$S_i =$ weighting factor for soil group i
$S_1 = 1.0$; $S_2 = 2.0$; $S_3 = 3.0$; $S_4 = 4.0$

Evapotranspiration:

Evapotranspiration is a common measure of an environment's water loss and is of great importance to the Central Valley's vast agriculture. The rate of evapotranspiration is different for different crops and for any particular crop it also varies with time and geographic location. There have been several efforts to document the geographic variation of potential evaporative demand for entire countries or regions. DWR (1975) has divided the entire state into 11 zones of similar evaporative demand and provided monthly evaporation rates for each principal crop that are grown in the corresponding region. MacGillivary (1976)

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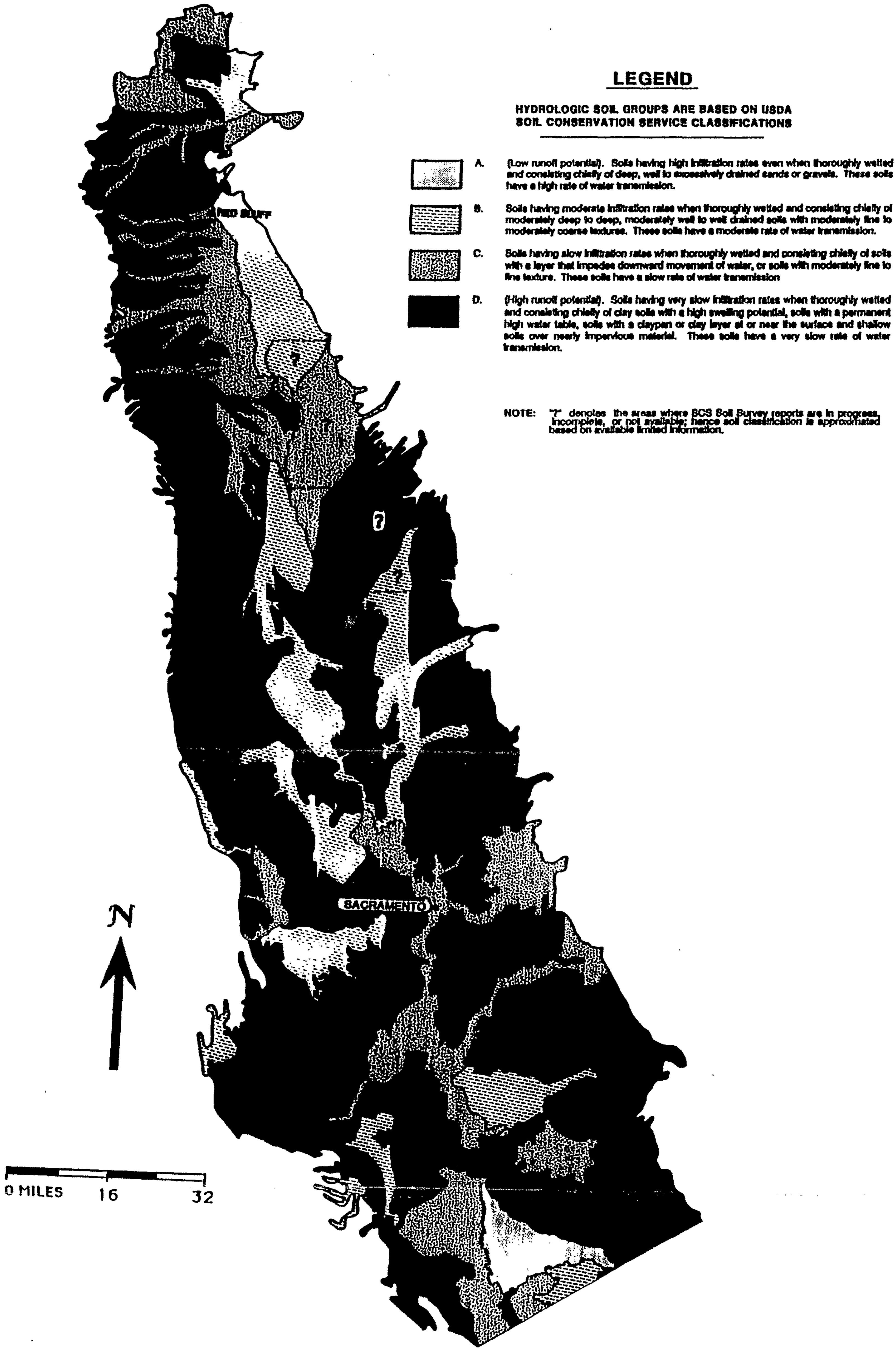


FIGURE 3.6(a)

HYDROLOGIC SOIL MAP
OF
SACRAMENTO VALLEY

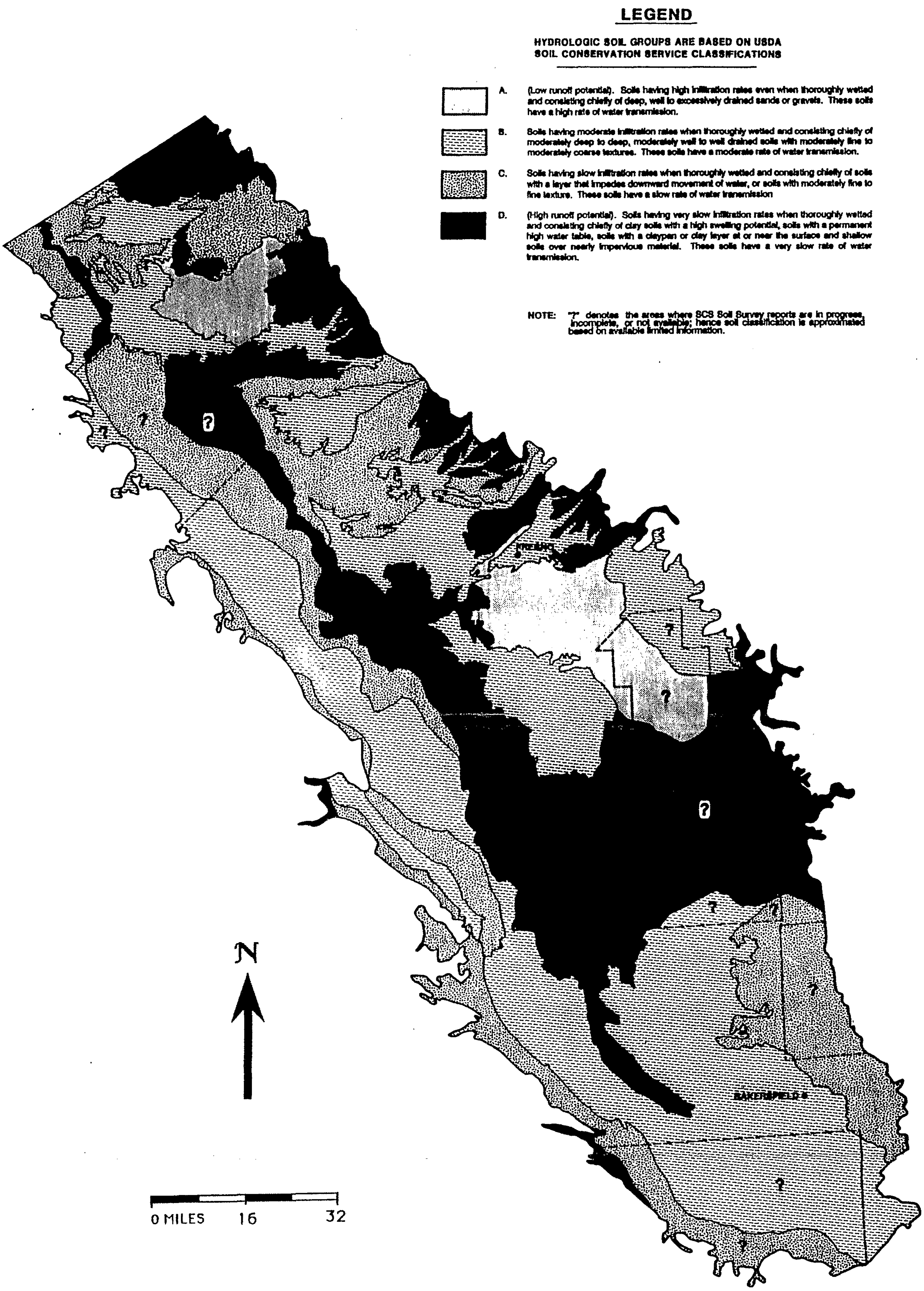


FIGURE 3.6 (b)

HYDROLOGIC SOIL MAP
OF
SAN JOAQUIN VALLEY

reevaluated the crop evapotranspiration values used in the DWR's Consumptive Use model and presented monthly crop evapotranspiration values for different zones as a function of long term mean annual precipitation in the corresponding zone. DWR's revised Consumptive Use model used these values in determining the crop ET demand for its study areas (DSA) which are different than the aforementioned zones. The current model employed these potential ET demand data from the revised Consumptive Use model. The Tulare Lake basin is not included in the consumptive use model and hence the potential ET demand data was prepared by using the MacGillivary (1976)'s tables and the long term mean annual precipitation in the region.

3.3 LAND USE

Central Valley's vast acreage of irrigated lands require an enormous quantity of water to maintain the healthy growth of crops. The Valley's irrigated acreage is on the rise, which implies an increased demand for irrigation water. The knowledge of the land use and crop acreages is very important for a groundwater-surface water model as it attempts to balance regional and subregional water budgets for surface water, groundwater, and soil moisture. DWR has made periodic detailed land use surveys to monitor the changes in cropping patterns and urban development. On the average, the areas of significant water use are surveyed once every seven years and the data compiled over a seven year period is adjusted to reflect the statewide land use condition for a single year. The annual crop acreage for each Depletion Study Area (DSA) was compiled for 1922 to 1980 period for DWR's Consumptive Use Model. Those crop acreages were used in the current model on a subregional basis. When a DSA is broken into several model subregions, the subregional crop acreage was obtained by prorating. The proration factor is obtained by processing the detailed land use survey data (on a 7 1/2 minute quadrangle basis) of 1976 - 1982. This land use data was combined and adjusted to obtain the element by element information of the crop/urban acreages for 1980. For any DSA which is broken into several subregions, a crop/urban factor was obtained for each subregion by dividing the subregional crop/urban acreage by the total crop/urban acreage in the DSA. These factors were derived from 1980 land use data used in distributing the crop acreages to model subregions for the entire period 1922-1980. A total of 14 crops were identified for the entire Central Valley, not all of them growing in all subregions. A list of the crops is given below:

1. Pasture
2. Alfalfa
3. Sugar Beet
4. Field Crops
5. Rice
6. Truck Crops
7. Tomato

8. Tomato (Hand picked)
9. Tomato (Machine picked)
10. Orchard
11. Grains
12. Vineyard
13. Cotton
14. Citrus and Olives

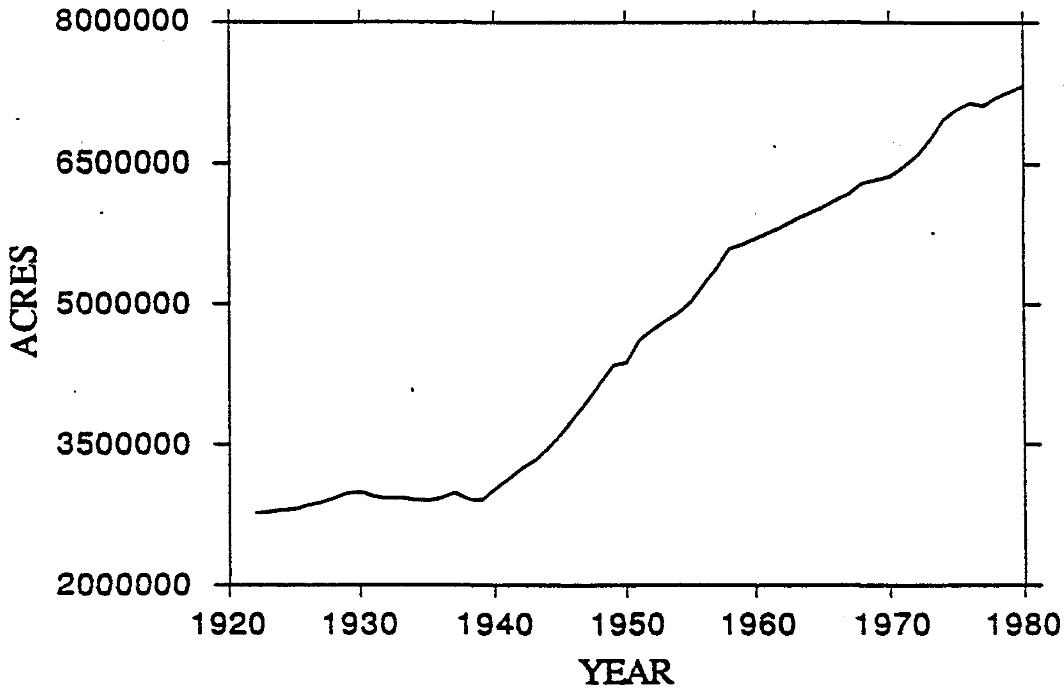
The crop classes 7 to 9 obviously demand an explanation. In the DWR's Consumptive Use model database, tomato acreages were reported in some of the DSAs without distinguishing the method of picking and in some DSA they were separately reported. Since the monthly ET values are different for hand picked and machine picked tomatoes, these three classes were incorporated to accommodate the inconsistency in reporting the tomato acreages. The growth of agricultural and urban acreage in the model area during the study period 1922-80 is shown in Fig. 3.7. The same for each model subregion is shown in Figs. 3.8 a - f.

The 7 1/2 minute quadrangle land use survey data was also used to determine the within element distribution of the ag/urban/native areas, given the land use data in a model subregion. The element by element crop acreage as a fraction of corresponding subregional crop acreages was determined by a preprocessor computer program using the 1980 adjusted land use data and the area of intersection between elements and quadrangles. For this purpose, a 7 1/2 minute quadrangle mesh was generated by digitization of USGS maps. However, the elemental distribution thus obtained was only for 1980 because such detail land use data were not available in computerized form for any period prior to 1970. To account for the temporal variability of this elemental land use distribution, the 1954-55 land use maps published by State Water Resources Board (1955) were used to delineate the 1954 land use distribution over all the finite elements of the model grid. Due to the lack of data, the elemental land use distribution prior to 1954 was taken to be the same as that in 1954 and for years between 1954 and 1980, a linear variation in land use distribution was assumed. This land use data was internally adjusted in the model to match the subregional crop acreage data obtained from Consumptive Use Model of DWR.

3.4 WATER USE

This section discusses the development of data pertaining to the agricultural and municipal water requirements in the Central Valley of California. Water needs in the region are predominantly for agriculture; urban needs make up less than 2 percent of the total water use in the Valley. In order to satisfy the water requirements of the vast acreage of irrigated lands, numerous water supply sources have been developed by the state, federal, and local governments. Surface water

AGRICULTURAL ACREAGE FOR THE ENTIRE MODEL REGION



URBAN ACREAGE FOR THE ENTIRE MODEL REGION

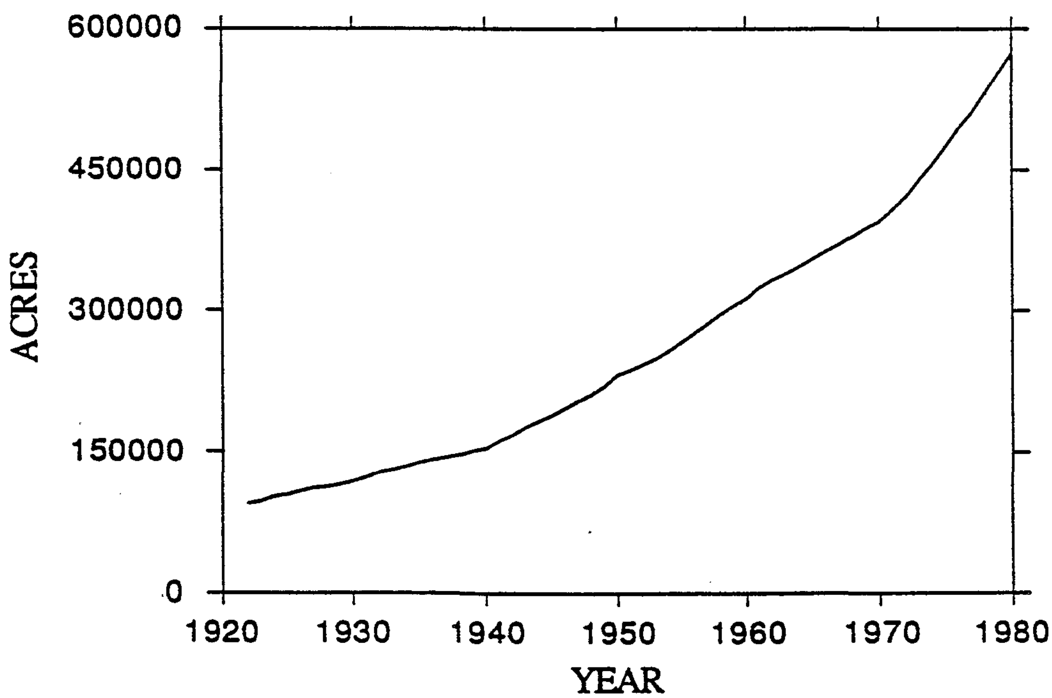


FIGURE 3.7

CENTRAL VALLEY HISTORIC LAND USE

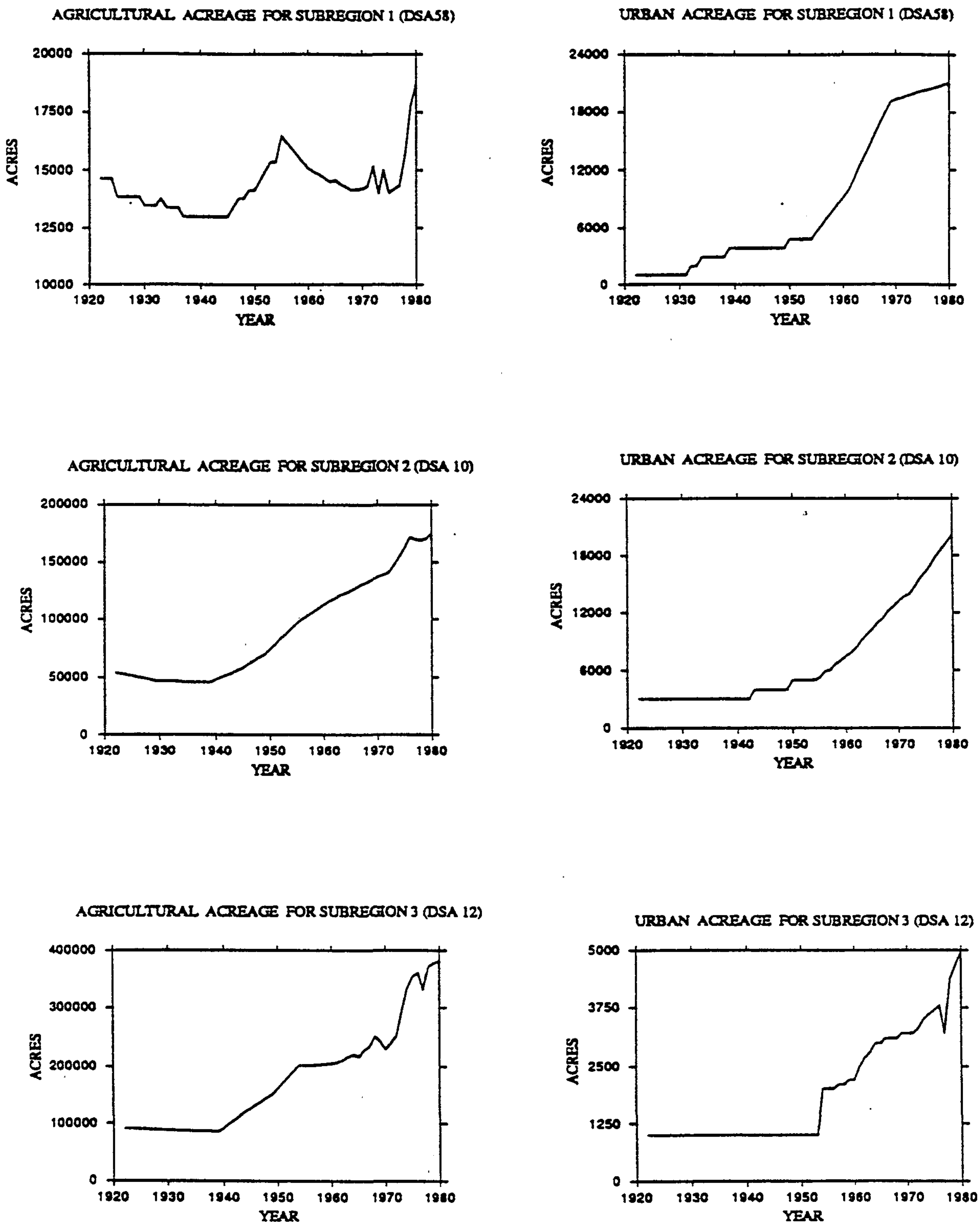
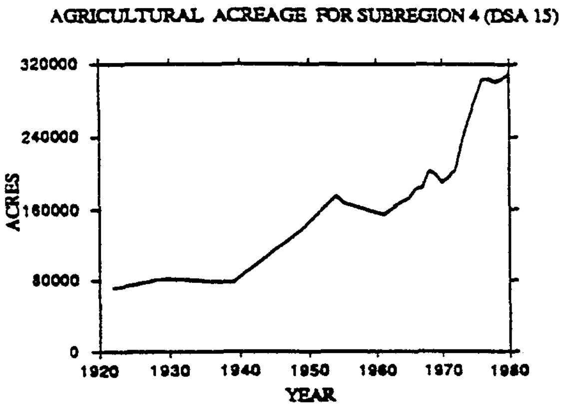
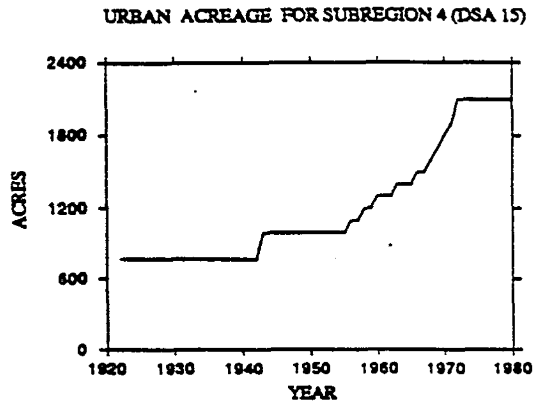


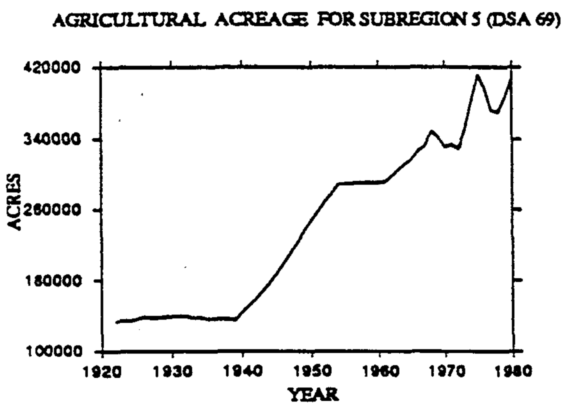
FIGURE 3.8(a)

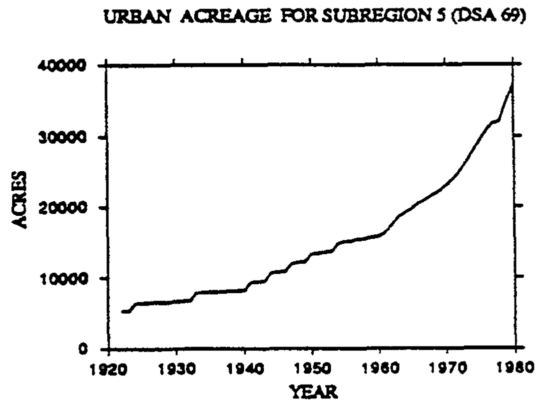
SUBREGIONAL LAND USE

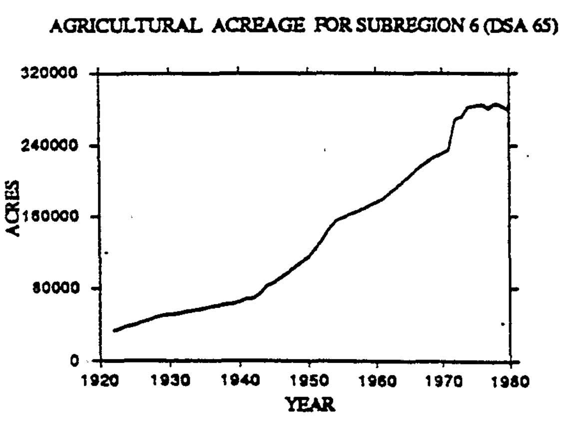
C—038378











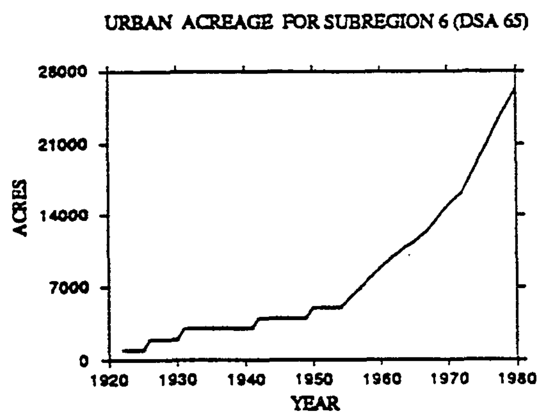


FIGURE 3.8(b)

SUBREGIONAL LAND USE

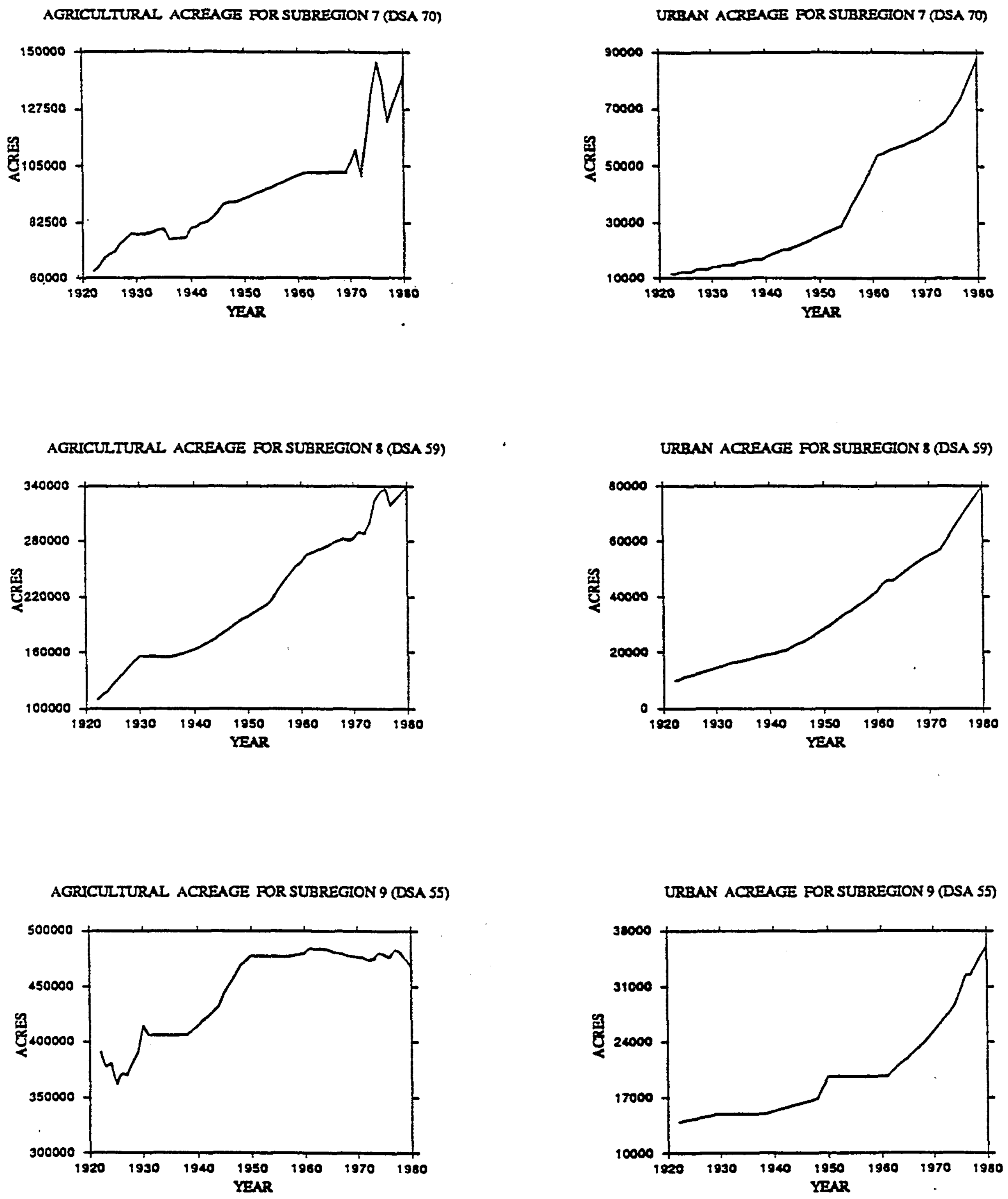


FIGURE 3.8(c)

SUBREGIONAL LAND USE

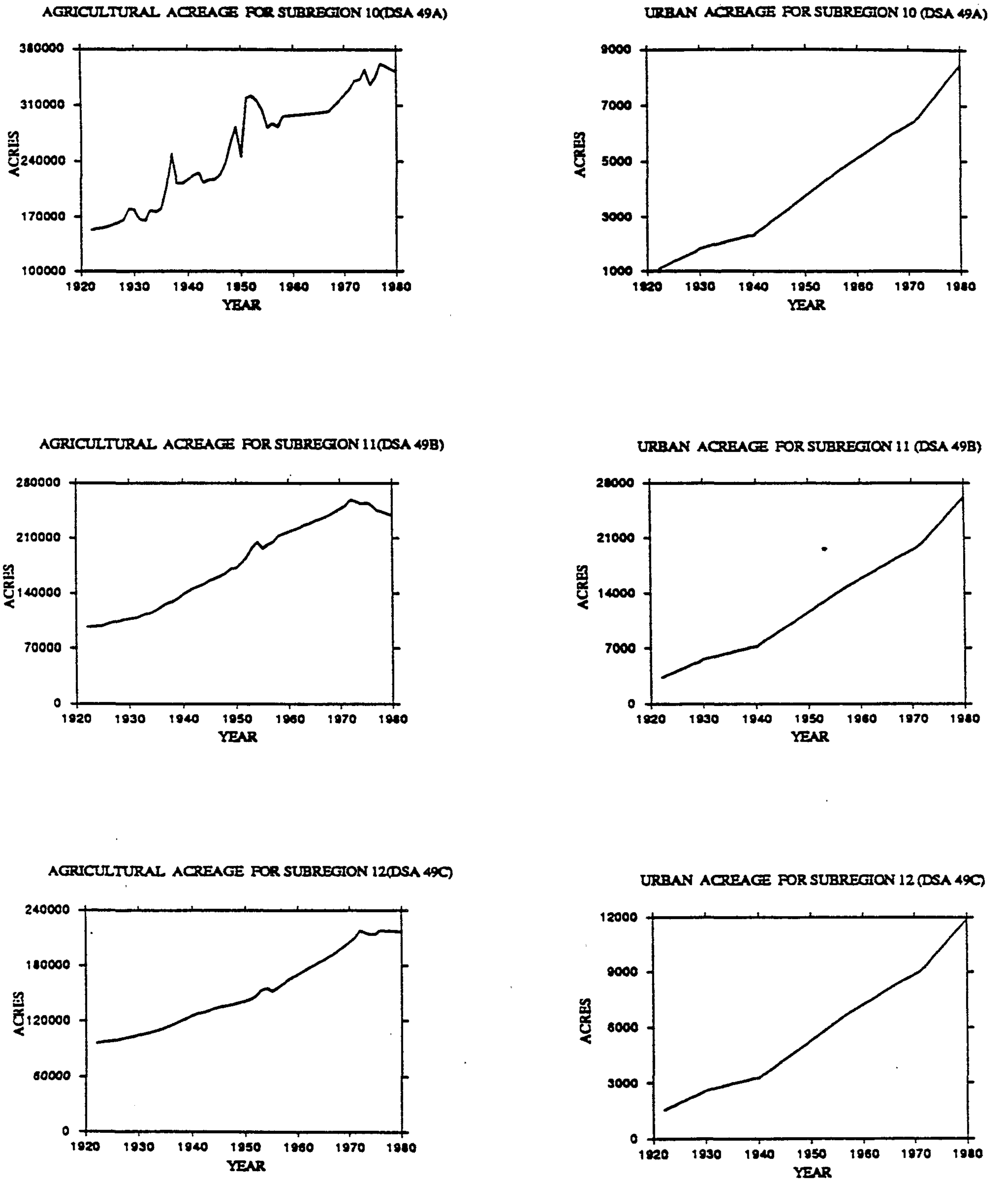


FIGURE 3.8(d)

SUBREGIONAL LAND USE

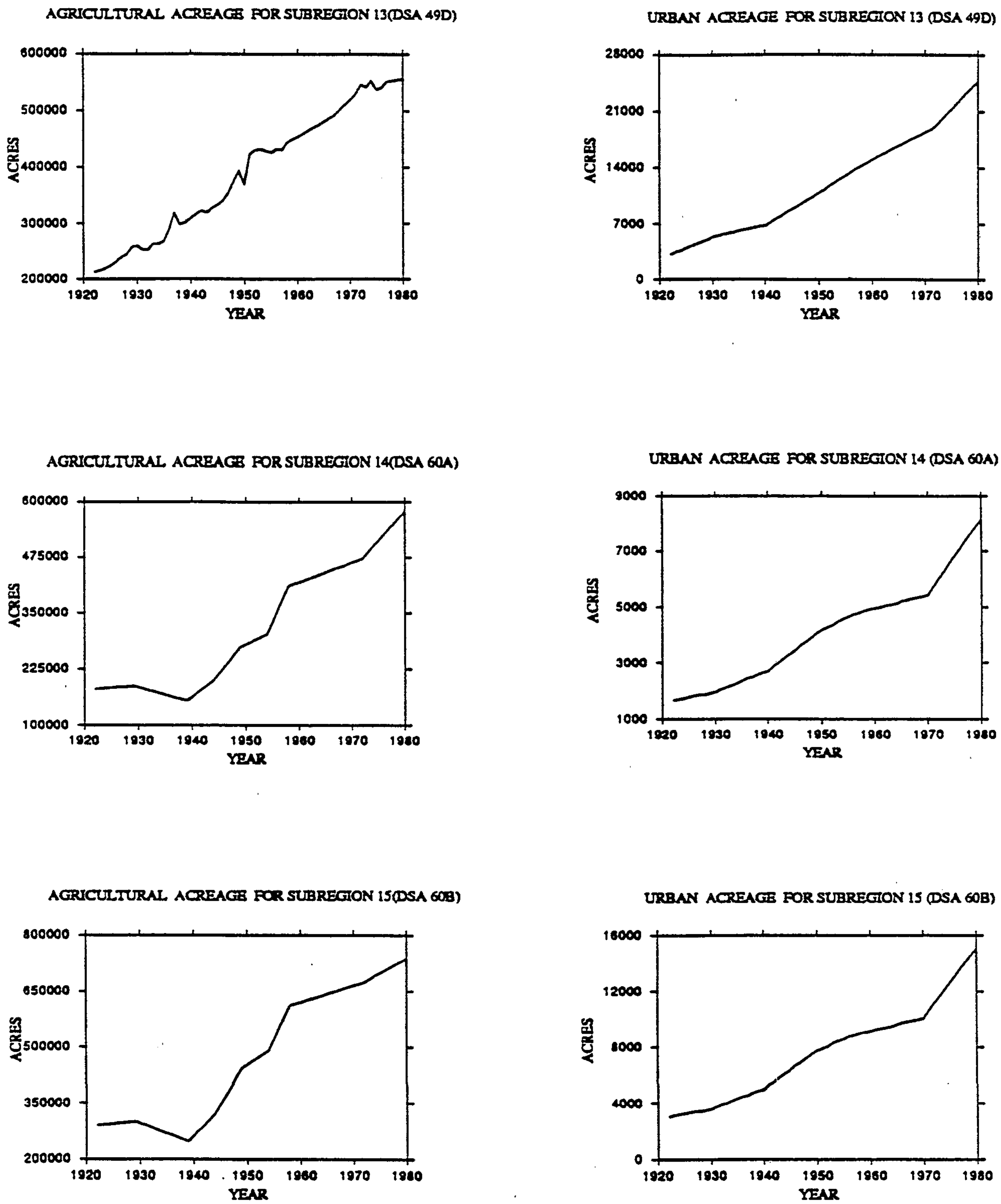
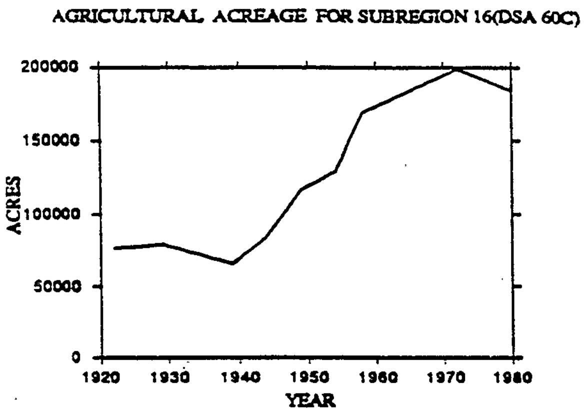
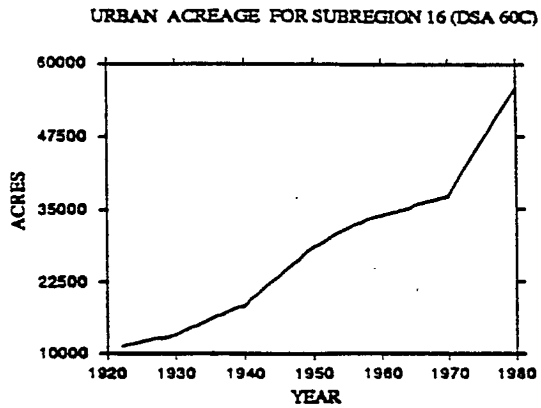
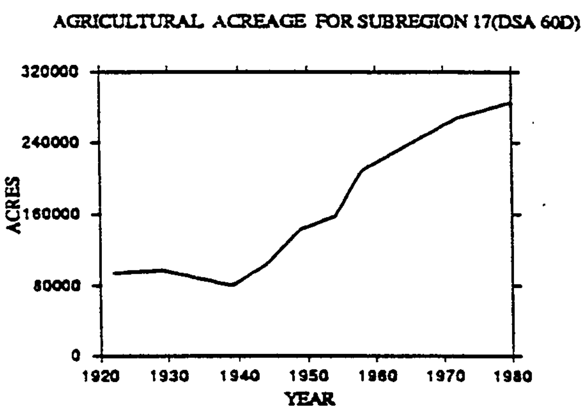


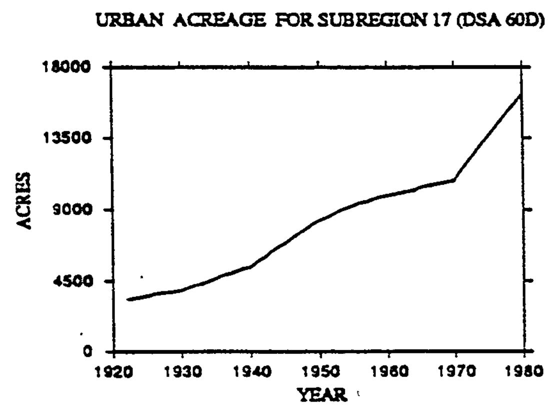
FIGURE 3.8(e)

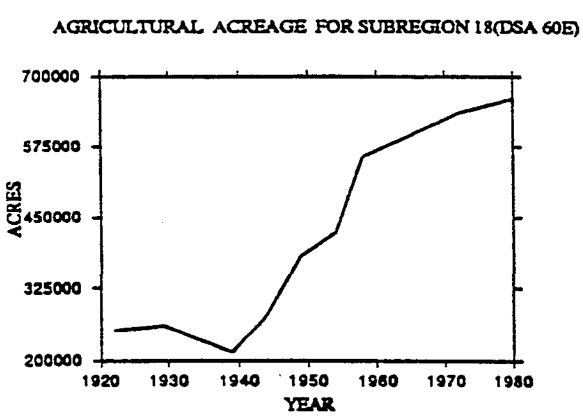
SUBREGIONAL LAND USE











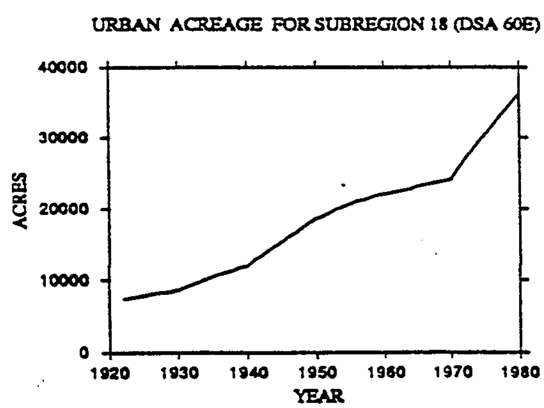
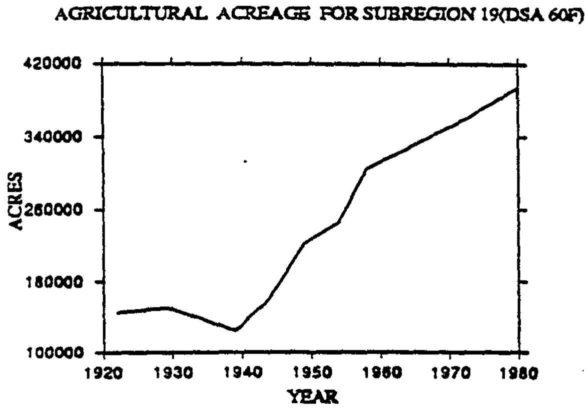
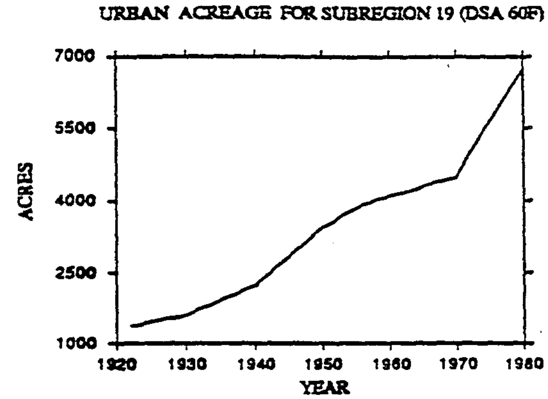
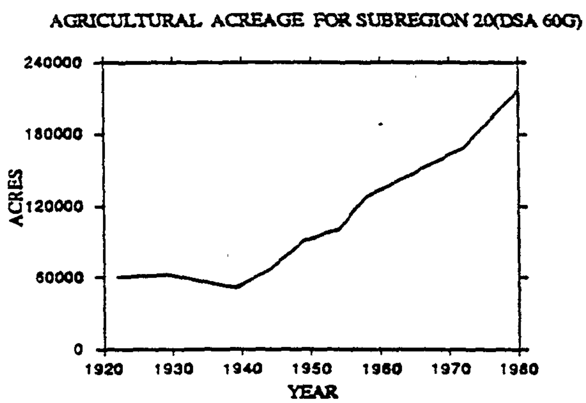


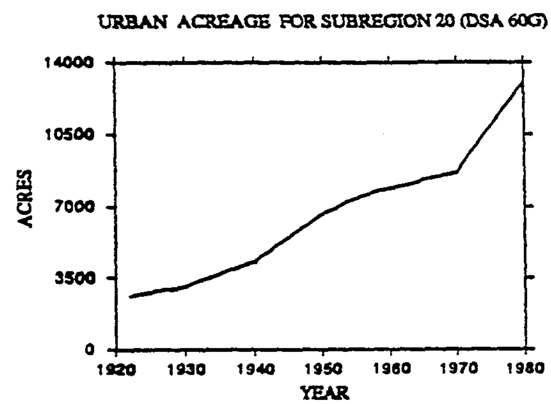
FIGURE 3.8(f)

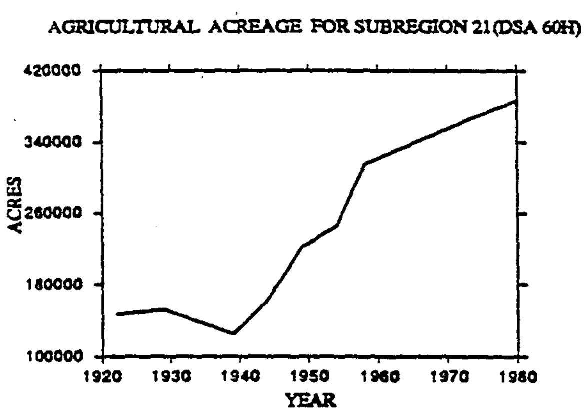
SUBREGIONAL LAND USE











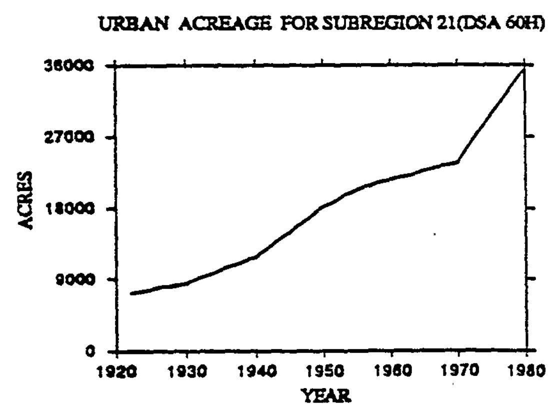


FIGURE 3.8 (g)

SUBREGIONAL LAND USE

diversions and groundwater pumpage for the region were determined from a comprehensive analysis of historic records maintained by these agencies. Where data was not available, estimates were developed from statistical analysis of the supporting data. (The data compilation and analysis is discussed in further detail in the following subsections). The Central Valley historic water use for the study period is presented in Fig. 3.9 by water year. The difference between the total water use and surface water diversions represents groundwater pumpage in the region. It is evident from this figure that the surface water diversions and groundwater pumping in the Central Valley increased at a similar rate from the 1920's to the early 1940's. From the mid 1940's through 1960, groundwater pumpage grew at a greater rate due to an increased demand from agricultural development, particularly in the San Joaquin Valley. This resulted in localized overdrafting of the underlying groundwater aquifer systems. Following 1960, surface water development increased enough to partly curtail the growth rate of groundwater pumping and, the increase in both remained relatively constant through 1980. Individual trends in subregional water use are shown in Figs. 3.10, a-d.

To validate the water use data for the Central Valley, a water budget analysis was conducted on both a regional and subregional basis. The components of the water budget are precipitation, the consumptive use of applied water (agricultural and urban), domestic indoor water use, surface water diversions, and groundwater pumping. The water budget analysis is very comprehensive in the sense that it accounts for all possible sources of water needs and demands in the Valley on a smaller spatial scale of 21 subregions of the model. The methods and assumptions are discussed below:

<u>Water Budget Analysis:</u>

Individual water budgets performed for each subregion of the study area are presented in Tables 3.4 a-u. Considerable effort was made to ensure that the data used in the water budget analysis was complete and accurate. When possible, the existing data was used, though it was soon discovered that for such a detailed study the existing data base was inadequate. Hence, a substantial amount of additional water use data was collected and compiled from various public and private agencies (see Tables 3.5 a-c). In many cases, similar data was obtained from more than one source, and was evaluated for consistency and accuracy. As a result, a consistent and comprehensive data set emerged.

The components of the water budget analysis are briefly discussed below:

- Annual rainfall values for each subregion were developed from existing database of DWR's Consumptive Use model and rain gaging stations data

TABLE 3.4A
WATER BUDGET FOR REGION 1 (DSA 58)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	26.2	41.4	0.6	42.0	2.3	49.7	24.9	72.3
1923	31.9	33.0	0.4	33.4	2.3	49.7	24.9	72.3
1924	12.1	46.9	0.6	47.5	2.3	44.6	22.3	64.6
1925	44.8	31.3	0.5	31.8	2.3	49.7	24.9	72.3
1926	28.5	38.7	0.6	39.3	2.3	48.3	24.2	70.2
1927	48.6	35.1	0.5	35.6	2.3	44.2	22.1	64.0
1928	33.7	39.4	0.6	40.0	2.4	54.7	27.4	79.7
1929	25.3	38.8	0.6	39.4	2.4	52.9	26.5	77.0
1930	26.6	37.9	0.6	38.5	2.4	58.9	29.5	86.0
1931	19.8	40.5	0.6	41.1	2.4	65.3	32.7	95.6
1932	24.7	37.8	1.4	39.2	2.4	57.5	28.8	83.9
1933	18.2	41.7	1.6	43.3	2.4	61.6	30.8	90.0
1934	27.8	36.4	2.0	38.4	2.4	63.0	31.5	92.1
1935	38.7	33.4	1.8	35.2	2.4	58.0	29.0	84.6
1936	35.9	32.7	1.8	34.5	3.1	65.8	32.9	95.6
1937	30.2	36.3	2.1	38.4	3.5	57.5	28.8	82.8
1938	51.7	33.4	1.8	35.2	3.6	54.7	27.4	78.5
1939	21.0	32.4	2.4	34.8	3.6	61.2	30.6	88.2
1940	46.9	35.8	2.7	38.5	3.6	54.3	27.2	77.9
1941	64.1	28.3	2.2	30.5	3.6	61.2	30.6	88.2
1942	44.0	30.7	2.3	33.0	3.6	53.8	26.9	77.1
1943	37.8	33.6	2.4	36.0	3.6	63.5	31.8	91.7
1944	23.9	35.2	2.7	37.9	4.3	69.9	35.0	100.6
1945	34.3	34.1	2.6	36.7	4.7	68.1	34.1	97.5
1946	37.9	37.0	2.7	39.7	4.7	74.5	37.3	107.1
1947	28.8	33.8	2.5	36.3	4.7	69.5	34.8	99.6
1948	38.5	27.8	2.1	29.9	4.8	63.5	31.8	90.5
1949	28.6	40.1	2.7	42.8	4.8	86.0	43.0	124.2
1950	24.1	41.6	3.7	45.3	4.8	86.5	43.3	125.0
1951	37.1	37.2	3.2	40.4	4.8	81.9	41.0	118.1
1952	45.1	37.5	3.2	40.7	5.9	84.2	42.1	120.4
1953	41.3	37.6	3.0	40.6	5.9	75.4	37.7	107.2
1954	34.9	39.8	3.2	43.0	6.0	86.5	43.3	123.8
1955	26.6	47.0	4.5	51.5	6.7	95.2	47.6	136.1
1956	47.0	43.4	4.7	48.1	7.1	95.7	47.9	136.5
1957	28.1	34.6	4.3	38.9	7.1	94.3	47.2	134.4
1958	59.2	31.3	4.2	35.5	7.2	76.8	38.4	108.0
1959	25.6	42.5	6.4	48.9	7.9	99.8	49.9	141.8
1960	27.5	42.0	6.8	48.8	8.3	98.0	49.0	138.7
1961	34.2	39.4	7.0	46.4	8.3	87.9	44.0	123.6
1962	34.4	40.0	8.0	48.0	8.4	90.6	45.3	127.5
1963	37.5	34.6	7.7	42.3	9.1	63.9	32.0	86.8
1964	21.6	40.9	9.9	50.8	9.5	75.4	37.7	103.6
1965	40.6	35.7	9.4	45.1	9.5	68.1	34.1	92.7
1966	28.6	42.2	12.1	54.3	9.5	80.2	40.1	110.8
1967	42.9	36.2	11.3	47.5	9.6	71.4	35.7	97.5
1968	31.6	38.4	13.0	51.4	10.3	79.2	39.6	108.5
1969	48.9	38.1	13.7	51.8	10.7	81.2	42.1	112.6
1970	45.6	38.1	14.5	52.6	10.7	82.2	41.1	112.6
1971	43.4	32.3	12.7	45.0	11.5	76.4	38.2	103.1
1972	22.5	36.3	14.1	50.4	11.9	86.1	43.1	117.3
1973	44.0	35.2	14.4	49.6	12.6	81.8	40.9	110.1
1974	52.4	27.8	12.3	40.1	13.1	79.3	39.7	105.9
1975	39.7	28.6	13.8	42.4	13.1	90.8	38.0	115.7
1976	23.6	24.4	12.4	36.8	14.3	95.8	45.0	126.5
1977	20.5	25.8	12.5	38.3	14.3	86.7	43.4	115.8
1978	57.8	30.8	13.7	44.5	15.1	72.1	36.1	93.1
1979	32.1	39.4	15.1	54.5	15.5	90.4	45.2	120.1
1980	41.8	37.5	13.7	51.2	16.3	90.2	48.0	121.9
AVG 22-80	35.1	36.3	5.7	41.9	6.7	72.3	36.1	101.7

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4B
WATER BUDGET FOR REGION 2 (DSA 10)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.7	155.4	2.4	157.8	3.6	85.0	84.1	165.5
1923	21.4	127.5	2.2	129.7	3.6	66.0	66.6	129.0
1924	8.8	160.2	2.4	162.6	3.6	7.0	120.9	124.3
1925	27.8	111.0	2.0	113.0	3.6	85.0	46.0	127.4
1926	20.3	125.7	2.2	127.9	3.6	57.0	68.4	121.8
1927	23.9	132.0	2.3	134.3	3.6	80.0	65.3	141.7
1928	19.3	124.8	2.3	127.1	3.6	71.0	62.5	129.9
1929	14.7	130.0	2.4	132.4	3.6	43.0	77.8	117.2
1930	18.1	123.9	2.4	126.3	3.6	76.0	60.0	132.4
1931	13.2	132.2	2.5	134.7	3.6	65.0	71.3	132.7
1932	16.3	130.0	2.4	132.4	3.6	86.0	61.5	143.9
1933	10.8	140.9	2.5	143.4	3.6	79.0	73.6	149.0
1934	16.7	127.2	2.5	129.7	3.6	84.0	59.9	140.3
1935	26.1	107.4	2.0	109.4	3.6	86.0	42.8	125.2
1936	22.3	107.1	2.1	109.2	4.3	86.0	42.7	124.4
1937	19.6	121.7	2.5	124.2	4.3	96.0	51.1	142.8
1938	31.7	111.4	2.2	113.6	4.3	89.0	45.1	129.8
1939	10.5	133.6	2.4	136.0	4.7	88.0	63.8	147.1
1940	25.7	123.0	2.3	125.3	4.7	91.0	53.7	140.0
1941	44.0	111.9	2.0	113.9	4.7	91.0	44.6	130.9
1942	30.0	118.5	2.0	120.5	4.8	99.0	47.1	141.3
1943	21.8	138.4	3.0	141.4	4.8	98.0	64.6	157.8
1944	15.3	149.6	3.1	152.7	4.8	109.0	70.2	174.4
1945	22.0	147.4	3.0	150.4	4.8	108.0	68.6	171.8
1946	20.0	166.6	3.2	169.8	4.8	109.0	85.4	189.6
1947	14.9	169.2	2.9	172.1	4.8	82.0	98.5	175.7
1948	23.5	132.0	2.3	134.3	5.5	93.0	60.5	148.0
1949	20.0	185.5	3.2	188.7	5.9	110.0	102.6	206.7
1950	14.6	209.9	4.1	214.0	5.9	114.0	125.5	233.6
1951	21.3	205.8	3.9	209.7	5.9	109.0	123.4	226.5
1952	27.3	203.1	3.6	206.7	6.0	119.0	116.2	229.2
1953	25.9	227.6	3.9	231.5	6.0	133.0	134.7	261.7
1954	19.9	222.5	3.6	226.1	6.0	116.0	136.8	246.8
1955	19.3	271.0	4.3	275.3	6.7	99.0	196.8	289.1
1956	28.1	253.9	4.5	258.4	7.1	115.0	170.9	278.8
1957	16.2	248.5	4.2	252.7	7.1	123.0	161.1	277.0
1958	39.9	216.9	4.2	221.1	7.2	102.0	137.9	232.7
1959	15.9	301.5	5.8	307.3	7.2	116.0	224.3	333.1
1960	16.3	288.5	6.0	294.5	7.9	120.0	207.9	320.0
1961	23.7	278.8	5.8	284.6	7.9	115.2	199.3	306.6
1962	21.7	297.9	6.6	304.5	8.3	126.4	203.0	321.1
1963	24.5	256.7	5.9	262.6	8.3	106.4	192.5	290.6
1964	14.8	316.2	7.5	323.7	8.3	84.7	229.3	305.7
1965	23.5	287.9	7.5	295.4	8.3	116.8	204.0	312.5
1966	17.6	354.0	9.3	363.3	8.4	148.6	253.1	393.3
1967	25.9	309.4	8.6	318.0	8.4	122.6	200.9	315.1
1968	19.4	331.1	9.6	340.7	9.1	146.5	236.4	373.8
1969	31.3	337.6	9.9	347.5	9.1	139.1	241.4	371.4
1970	24.3	336.7	10.2	346.9	9.5	148.9	239.7	379.1
1971	23.2	344.4	10.9	355.3	9.5	146.6	249.6	386.7
1972	11.1	369.2	11.5	380.7	9.6	137.1	287.6	415.1
1973	32.5	328.2	11.1	339.3	10.3	148.9	267.2	405.8
1974	27.8	310.0	11.0	321.0	10.7	153.3	258.2	400.8
1975	23.7	323.5	11.9	335.4	10.7	160.0	291.6	440.9
1976	11.5	393.0	12.9	405.9	11.5	123.5	353.8	465.8
1977	12.8	374.0	13.6	387.6	11.9	68.3	396.3	452.7
1978	38.1	314.0	13.2	327.2	11.9	120.6	244.9	353.6
1979	21.5	330.9	14.7	345.6	11.9	143.1	254.9	386.1
1980	31.4	330.4	14.1	344.5	12.7	146.0	252.1	385.4
AVG 22-80	21.7	218.9	5.5	224.4	6.6	104.9	146.6	244.9

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4C
WATER BUDGET FOR REGION 3 (DSA 12)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	16.5	292.0	0.7	292.7	1.9	404.5	79.9	482.5
1923	20.8	275.8	0.8	276.6	1.9	404.5	66.7	469.3
1924	9.1	291.9	0.8	292.7	1.9	394.9	83.8	476.8
1925	23.6	247.4	0.7	248.1	2.3	404.5	42.9	445.1
1926	18.4	277.3	0.7	278.0	2.3	522.2	18.7	538.6
1927	20.4	276.9	0.7	277.6	2.3	520.8	19.0	537.5
1928	17.5	257.5	0.7	258.2	2.3	466.4	25.5	489.6
1929	12.2	265.8	0.8	266.6	2.3	477.1	28.2	503.0
1930	16.1	261.0	0.8	261.8	2.3	474.7	25.0	497.4
1931	10.4	285.1	0.8	285.9	2.3	572.3	18.0	588.0
1932	16.0	272.0	0.8	272.8	2.3	472.9	35.3	505.9
1933	9.1	286.9	0.8	287.7	2.3	480.1	44.9	522.7
1934	14.2	272.1	0.7	272.8	2.3	449.0	45.2	491.9
1935	22.0	234.4	0.6	235.0	2.3	390.0	37.9	425.6
1936	18.8	250.2	0.7	250.9	2.3	445.0	28.3	471.0
1937	17.7	265.4	0.8	266.2	2.3	484.0	24.9	506.6
1938	27.2	240.0	0.7	240.7	2.3	378.0	47.7	423.4
1939	7.3	284.3	0.7	285.0	2.3	567.0	18.0	582.7
1940	22.4	265.6	0.7	266.3	2.3	474.0	29.2	500.9
1941	36.9	260.7	0.6	261.3	2.3	513.0	18.0	528.7
1942	25.7	298.1	0.6	298.7	2.4	572.0	18.0	587.6
1943	16.7	356.1	0.8	356.9	2.4	605.0	51.2	653.8
1944	15.2	379.2	0.8	380.0	2.4	694.6	33.3	725.5
1945	16.7	372.9	0.7	373.6	2.4	700.7	25.3	723.6
1946	15.5	419.3	0.7	420.0	2.4	737.6	49.2	784.4
1947	13.2	424.9	0.8	425.7	2.4	746.5	50.3	794.4
1948	19.4	352.0	0.6	352.6	2.4	641.9	32.2	671.7
1949	15.1	453.1	0.7	453.8	2.4	812.1	46.7	856.4
1950	11.7	490.9	0.8	491.7	2.4	759.7	99.1	856.4
1951	18.5	518.6	0.7	519.3	2.4	837.5	90.4	925.5
1952	24.0	522.7	0.7	523.4	2.4	816.6	102.0	916.2
1953	18.3	585.3	0.8	586.1	2.4	948.6	100.0	1046.2
1954	15.2	593.4	1.5	594.9	2.4	884.2	132.6	1014.4
1955	14.0	647.4	1.6	649.0	2.4	892.0	172.3	1061.9
1956	24.0	621.5	1.7	623.2	2.4	901.0	148.4	1047.0
1957	13.4	615.8	1.5	617.3	2.4	889.6	148.2	1035.4
1958	28.5	539.3	1.4	540.7	2.4	748.7	142.6	888.9
1959	12.9	658.7	1.8	660.5	2.4	1007.4	136.4	1141.4
1960	12.1	639.4	1.7	641.1	2.4	974.2	134.0	1105.8
1961	16.0	620.5	1.9	622.4	2.4	939.8	132.6	1070.0
1962	15.9	656.2	2.3	658.5	2.4	945.0	171.6	1114.2
1963	23.1	571.9	1.9	573.8	2.4	783.4	155.2	936.2
1964	11.7	698.3	2.6	700.9	2.4	898.5	204.6	1100.7
1965	17.9	620.7	2.5	623.2	2.4	863.6	173.5	1034.7
1966	12.0	716.6	2.6	719.2	2.4	911.0	218.9	1127.5
1967	25.6	605.6	2.1	607.7	2.4	794.8	163.9	956.3
1968	15.2	732.6	2.5	735.1	2.4	983.5	218.0	1199.1
1969	23.8	708.1	2.4	710.5	2.4	861.6	199.2	1058.4
1970	19.0	658.7	2.4	661.1	2.4	837.7	211.1	1046.4
1971	15.5	687.5	2.6	690.1	2.4	856.0	219.4	1073.0
1972	9.2	738.4	2.9	741.3	2.4	896.0	290.6	1184.2
1973	27.8	754.0	2.7	756.7	2.4	877.7	222.5	1097.8
1974	20.5	774.9	2.7	777.6	2.4	930.5	231.8	1159.9
1975	18.3	843.9	2.9	846.8	2.4	989.5	268.3	1255.4
1976	7.1	958.8	3.2	962.0	3.1	1031.6	394.4	1422.9
1977	8.7	814.0	2.7	816.7	3.1	706.7	401.8	1105.4
1978	26.0	832.3	3.2	835.5	3.1	976.1	284.5	1257.5
1979	16.2	905.7	3.8	909.5	3.5	1180.3	264.0	1440.8
1980	25.2	921.2	3.9	925.1	3.5	992.9	346.4	1335.8
AVG 22-80	17.7	502.9	1.5	504.4	2.4	724.1	122.4	844.1

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4D
WATER BUDGET FOR REGION 4 (DSA 15)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.0	179.2	0.0	179.2	1.2	337.5	19.5	355.8
1923	18.9	172.7	0.0	172.7	1.2	337.5	17.7	354.0
1924	8.2	209.3	0.0	209.3	1.2	341.1	28.5	368.4
1925	21.4	155.7	0.0	155.7	1.2	249.5	17.9	266.2
1926	16.7	177.2	0.0	177.2	1.2	354.8	18.0	371.6
1927	18.5	202.4	0.0	202.4	1.2	419.2	21.5	439.5
1928	15.8	186.0	0.0	186.0	1.2	357.6	20.3	376.7
1929	11.1	192.5	0.0	192.5	1.2	339.9	23.3	362.0
1930	14.6	179.1	0.0	179.1	1.2	341.3	19.3	359.4
1931	9.4	186.5	0.0	186.5	1.2	448.7	15.5	463.0
1932	14.5	182.4	0.0	182.4	1.2	306.1	22.3	327.2
1933	8.3	205.6	0.0	205.6	1.2	336.9	27.5	363.2
1934	12.8	192.4	0.0	192.4	1.2	362.0	21.9	382.7
1935	19.9	173.6	0.0	173.6	1.2	325.0	18.7	342.5
1936	17.1	183.2	0.0	183.2	1.2	334.0	20.9	353.7
1937	16.1	195.9	0.0	195.9	1.2	369.0	22.5	390.3
1938	24.6	182.6	0.0	182.6	1.2	336.0	20.6	355.4
1939	6.6	218.6	0.0	218.6	1.2	427.0	25.9	451.7
1940	20.4	193.1	0.0	193.1	1.2	338.0	23.6	360.4
1941	33.5	212.9	0.0	212.9	1.2	391.0	26.4	416.2
1942	23.4	255.2	0.0	255.2	1.2	467.0	35.5	501.3
1943	15.2	290.7	0.8	291.5	1.2	575.0	40.9	614.7
1944	13.8	307.9	0.8	308.7	1.2	636.4	42.7	677.9
1945	15.2	308.3	0.7	309.0	1.2	649.3	41.9	690.0
1946	14.1	350.7	0.7	351.4	1.2	642.4	59.6	700.8
1947	12.0	345.2	0.8	346.0	1.2	630.5	58.3	687.6
1948	17.6	296.0	0.6	296.6	1.2	596.1	41.2	636.1
1949	13.7	372.9	0.7	373.6	1.2	652.9	68.5	720.2
1950	10.6	385.2	0.8	386.0	1.2	670.3	72.6	741.7
1951	16.8	387.1	0.7	387.8	1.2	715.5	69.2	783.5
1952	21.7	402.5	0.7	403.2	1.2	599.4	87.7	685.9
1953	16.6	436.8	0.8	437.6	1.2	697.4	95.2	791.4
1954	13.8	444.0	0.8	444.8	1.2	760.8	92.4	852.0
1955	12.7	468.0	0.9	468.9	1.2	741.0	107.2	847.0
1956	21.8	441.4	0.9	442.3	1.2	543.0	114.3	656.1
1957	12.1	437.0	0.9	437.9	1.2	594.4	106.3	699.5
1958	25.9	381.2	0.8	382.0	1.2	524.3	84.7	607.8
1959	11.7	449.8	1.0	450.8	1.2	714.6	100.3	813.7
1960	10.9	431.3	1.0	432.3	1.2	733.8	88.8	821.4
1961	14.6	407.3	1.1	408.4	1.2	763.2	74.4	836.4
1962	14.4	439.6	1.1	440.7	1.2	669.0	112.6	780.4
1963	20.9	401.5	1.0	402.5	1.2	584.6	102.4	685.8
1964	10.7	493.4	1.2	494.6	1.2	673.5	135.4	807.7
1965	16.2	457.5	1.2	458.7	1.2	501.4	118.6	618.8
1966	10.8	538.6	1.4	540.0	1.2	620.0	147.3	766.1
1967	23.3	449.9	1.1	451.0	1.2	385.2	113.4	497.4
1968	13.8	559.3	1.3	560.6	1.2	653.5	153.6	805.9
1969	21.6	541.7	1.4	543.1	1.2	458.4	138.3	595.5
1970	17.2	507.6	1.4	509.0	1.2	590.3	151.7	740.8
1971	14.1	524.1	1.7	525.8	1.2	635.0	157.2	791.0
1972	8.4	567.3	1.7	569.0	1.2	633.0	212.0	843.8
1973	25.2	565.0	1.6	566.6	1.2	634.3	161.7	794.8
1974	18.6	567.5	1.7	569.2	1.2	636.5	174.8	810.1
1975	16.6	602.9	1.7	604.6	1.2	634.5	201.3	834.6
1976	6.5	703.8	1.7	705.5	1.2	954.6	295.8	1249.2
1977	7.9	654.9	1.7	656.6	1.2	473.6	304.0	776.4
1978	23.6	503.0	1.6	504.6	1.2	634.0	139.6	772.4
1979	14.7	571.9	1.7	573.6	1.2	634.4	183.0	816.2
1980	22.8	606.8	1.6	608.4	1.2	633.4	206.7	838.9
AVG 22-80	16.0	366.7	0.7	367.4	1.2	535.6	86.8	621.2

SOURCES OF DATA--- RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4E
WATER BUDGET FOR REGION 5 (DSA 69)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	21.1	375.1	4.3	379.4	6.0	535.5	125.5	655.0
1923	24.8	347.2	3.8	351.0	6.0	534.2	100.2	628.4
1924	11.4	394.8	5.3	400.1	6.0	466.2	170.0	630.2
1925	28.4	320.2	4.2	324.4	6.0	568.3	67.9	630.2
1926	23.4	363.0	4.9	367.9	6.0	619.4	88.5	701.9
1927	27.7	369.2	4.9	374.1	6.7	657.7	82.2	733.2
1928	20.9	379.2	4.9	384.1	7.1	630.4	99.0	722.3
1929	16.6	378.4	5.2	383.6	7.1	624.1	100.6	717.6
1930	21.4	371.6	5.3	376.9	7.1	621.3	95.6	709.8
1931	13.1	411.2	5.2	416.4	7.2	637.6	125.9	756.3
1932	18.4	388.0	5.4	393.4	7.2	669.8	94.8	757.4
1933	13.0	400.2	6.6	406.8	7.2	677.6	104.1	774.5
1934	17.1	389.2	6.6	395.8	7.9	609.5	116.2	717.8
1935	28.2	329.4	5.5	334.9	8.3	557.2	79.6	628.5
1936	25.4	352.1	5.9	358.0	8.3	634.4	75.8	701.9
1937	23.0	375.9	6.4	382.3	8.4	677.0	83.2	751.8
1938	36.0	336.7	5.7	342.4	8.4	638.4	62.4	692.4
1939	11.5	403.2	6.4	409.6	9.1	690.7	102.4	784.0
1940	29.1	374.1	6.4	380.5	9.5	631.4	95.6	717.5
1941	41.1	350.9	6.2	357.1	9.5	636.3	74.6	701.4
1942	34.6	361.2	6.2	367.4	10.3	733.3	55.6	778.6
1943	24.1	454.4	7.0	461.4	10.7	813.5	109.3	912.1
1944	21.4	496.6	8.4	505.0	10.8	915.4	115.7	1020.3
1945	22.4	511.9	8.2	520.1	11.5	914.5	130.0	1033.0
1946	20.6	576.1	8.4	584.5	11.9	976.0	171.6	1135.7
1947	17.1	572.7	9.0	581.7	12.7	923.5	188.2	1099.0
1948	23.6	482.8	7.4	490.2	13.1	776.9	148.7	912.5
1949	16.6	666.6	9.7	676.3	13.1	937.0	288.3	1212.2
1950	15.9	678.7	10.7	689.4	13.9	923.2	309.8	1219.1
1951	24.4	717.4	10.3	727.7	14.3	967.3	337.2	1290.2
1952	32.8	700.6	9.8	710.4	14.3	948.3	324.3	1258.3
1953	22.5	740.7	10.4	751.1	15.1	1081.6	315.7	1382.2
1954	20.0	739.2	10.8	750.0	15.5	1027.4	338.1	1350.0
1955	16.9	830.5	12.3	842.8	15.5	1033.4	455.0	1472.9
1956	30.7	797.9	11.9	809.8	16.2	996.1	428.9	1408.8
1957	17.6	745.0	11.0	756.0	16.7	980.0	366.8	1330.1
1958	35.4	647.9	9.5	657.4	16.7	925.8	270.8	1179.9
1959	16.9	820.1	12.6	832.7	17.4	1122.8	399.4	1504.8
1960	16.1	770.8	12.6	783.4	17.9	1098.8	347.8	1428.7
1961	19.7	781.8	12.6	794.4	17.9	1054.4	381.7	1418.2
1962	19.9	840.3	14.1	854.4	18.6	1151.7	418.7	1551.8
1963	30.8	721.9	11.8	733.7	19.1	957.8	378.8	1317.5
1964	16.6	882.5	14.9	897.4	19.8	1101.1	476.7	1558.0
1965	22.3	843.8	14.8	858.6	19.8	1107.0	422.7	1509.9
1966	15.7	979.7	17.3	997.0	20.3	1175.9	499.1	1654.7
1967	32.5	810.0	14.4	824.4	21.0	991.5	410.4	1380.9
1968	19.4	958.5	16.8	975.3	21.4	1261.1	537.9	1777.6
1969	32.7	917.4	16.8	934.2	21.5	1168.5	472.9	1619.9
1970	26.2	894.3	17.8	912.1	22.2	1148.0	489.8	1615.6
1971	20.6	915.6	19.0	934.6	22.6	1134.3	507.5	1619.2
1972	12.5	926.1	20.1	946.2	23.4	1247.1	633.0	1856.7
1973	34.0	934.9	20.0	954.9	23.8	1172.0	529.9	1678.1
1974	30.9	930.6	19.4	950.0	24.6	1155.8	542.8	1674.0
1975	22.9	1066.7	22.1	1088.8	25.0	1319.2	603.6	1897.8
1976	11.5	1069.0	24.2	1093.2	25.8	1308.9	780.0	2063.1
1977	10.2	1018.3	25.8	1044.1	26.2	903.8	885.9	1763.5
1978	31.6	831.8	22.6	854.4	27.0	1089.8	443.5	1506.3
1979	20.6	951.1	26.7	977.8	27.4	1308.0	504.8	1785.4
1980	27.6	1063.6	27.9	1091.5	28.2	1218.4	717.2	1907.4
AVG 22-80	22.7	645.1	11.4	656.5	14.8	904.8	299.7	1189.8

SOURCES OF DATA--- RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4F
WATER BUDGET FOR REGION 6 (DSA 65)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	18.6	87.9	0.8	88.7	3.6	156.7	23.0	176.1
1923	21.5	93.5	0.8	94.3	3.6	162.5	23.0	181.9
1924	10.0	107.8	0.8	108.6	3.6	44.0	48.9	89.3
1925	22.5	89.8	0.7	90.5	3.6	165.7	23.0	185.1
1926	21.7	100.5	1.5	102.0	3.6	193.3	23.0	212.7
1927	24.1	103.6	1.4	105.0	4.3	180.5	23.0	199.2
1928	19.0	113.0	1.4	114.4	4.3	59.4	47.2	102.3
1929	14.1	125.9	1.5	127.4	4.7	97.0	42.4	134.7
1930	17.8	122.7	1.5	124.2	4.7	141.6	24.4	161.3
1931	11.6	136.1	2.4	138.5	4.7	89.2	53.7	138.2
1932	19.8	137.4	2.4	139.8	4.7	80.4	58.3	134.0
1933	12.6	140.9	2.4	143.3	4.7	47.5	74.9	117.7
1934	14.2	145.0	2.5	147.5	4.7	92.1	59.5	146.9
1935	23.7	127.7	2.1	129.8	4.8	97.2	44.1	136.5
1936	23.4	141.3	2.2	143.5	4.8	183.2	23.0	201.4
1937	21.4	151.7	2.6	154.3	4.8	168.7	35.1	199.0
1938	31.6	146.2	2.3	148.5	4.8	151.7	37.2	184.1
1939	8.4	180.1	2.4	182.5	4.8	128.1	72.6	195.9
1940	27.0	157.8	2.4	160.2	4.8	150.2	46.2	191.6
1941	40.2	145.9	1.9	147.8	4.8	145.4	39.0	179.6
1942	29.1	155.9	2.8	158.7	4.8	153.2	43.9	192.3
1943	22.2	188.0	3.2	191.2	5.5	190.7	53.7	238.9
1944	17.8	210.4	3.1	213.5	5.9	173.2	78.9	246.2
1945	18.8	217.2	3.1	220.3	5.9	215.5	66.4	276.0
1946	17.8	238.7	3.2	241.9	6.0	273.2	59.7	326.9
1947	14.4	249.2	3.0	252.2	6.0	119.5	139.1	252.6
1948	16.8	234.2	2.6	236.8	6.0	168.2	101.3	263.5
1949	16.6	281.1	3.2	284.3	6.7	222.5	118.8	334.6
1950	15.4	304.4	4.2	308.6	7.1	172.5	167.5	332.9
1951	21.5	314.8	3.8	318.6	7.2	221.0	152.3	366.1
1952	26.8	328.3	3.8	332.1	7.2	212.5	170.2	375.5
1953	23.3	364.1	3.9	368.0	8.3	236.5	194.2	422.4
1954	16.9	381.1	3.8	384.9	8.3	248.7	205.2	445.6
1955	17.2	402.5	4.5	407.0	8.4	238.9	234.4	464.9
1956	30.1	424.4	5.2	429.6	9.1	211.9	275.1	477.9
1957	14.7	401.9	5.2	407.1	9.5	233.1	237.8	461.4
1958	32.9	362.7	5.1	367.8	9.5	177.5	226.5	394.5
1959	16.0	442.8	6.9	449.7	9.6	216.5	295.3	502.2
1960	14.4	432.3	7.3	439.6	10.3	259.9	258.3	507.9
1961	15.3	453.0	7.7	460.7	10.7	286.6	266.3	542.2
1962	18.2	469.5	8.2	477.7	11.9	294.3	296.7	579.1
1963	30.9	389.3	6.8	396.1	11.9	239.7	250.5	478.3
1964	13.9	502.6	9.1	511.7	13.1	317.6	344.4	648.9
1965	22.0	466.7	8.8	475.5	13.1	285.1	248.0	520.0
1966	14.2	525.6	10.2	535.8	14.3	327.6	330.1	643.4
1967	33.5	428.5	8.5	437.0	15.0	271.5	248.3	504.8
1968	13.5	509.3	10.7	520.0	15.5	334.6	336.4	655.5
1969	28.5	510.5	11.2	521.7	16.2	316.4	276.3	576.5
1970	23.2	513.7	11.8	525.5	16.7	321.6	260.3	565.2
1971	19.4	534.6	12.7	547.3	17.4	381.6	277.9	642.1
1972	11.4	586.0	13.4	599.4	17.9	303.1	352.6	637.8
1973	32.3	505.6	13.1	518.7	17.9	363.2	298.1	643.4
1974	25.5	478.6	13.8	492.4	18.6	355.7	254.5	591.6
1975	20.9	491.0	15.5	506.5	19.1	324.8	315.6	621.3
1976	8.7	595.4	17.3	612.7	19.8	363.0	452.2	795.4
1977	9.1	564.5	19.0	583.5	20.3	210.0	550.5	740.2
1978	33.1	437.6	18.1	455.7	21.0	352.7	223.1	554.8
1979	19.7	467.2	20.2	487.4	21.4	376.8	243.9	599.3
1980	31.1	434.5	19.4	453.9	22.2	366.3	213.6	557.7
AVG 22-80	20.5	311.1	6.3	317.3	9.6	218.2	168.5	377.1

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4G
WATER BUDGET FOR REGION 7 (DSA 70)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	23.4	155.3	9.0	164.3	4.8	129.4	72.3	196.9
1923	27.7	150.6	8.5	159.1	4.8	174.6	63.6	233.4
1924	11.0	188.5	10.3	198.8	4.8	187.4	94.3	276.9
1925	25.1	153.5	8.4	161.9	5.5	164.2	66.9	225.6
1926	21.2	167.4	9.2	176.6	5.9	201.2	75.0	270.3
1927	26.4	172.0	9.5	181.5	5.9	245.7	74.5	314.3
1928	16.8	184.8	10.2	195.0	6.0	246.7	85.3	326.0
1929	14.2	198.3	10.4	208.7	6.0	221.3	98.9	314.2
1930	18.5	190.9	11.2	202.1	6.7	226.6	93.1	313.0
1931	14.1	197.3	11.1	208.4	7.1	227.6	98.0	318.5
1932	21.2	200.9	12.0	212.9	7.1	233.0	101.1	327.0
1933	13.7	204.0	12.2	216.2	7.2	228.2	104.3	325.3
1934	15.6	211.2	12.5	223.7	7.2	249.0	108.2	350.0
1935	26.8	183.1	11.4	194.5	7.9	253.5	84.2	329.8
1936	23.2	184.0	12.2	196.2	8.3	245.4	86.4	323.5
1937	25.3	189.5	13.4	202.9	8.3	235.0	92.9	319.6
1938	29.5	182.5	12.8	195.3	8.4	258.4	84.4	334.4
1939	12.7	198.0	12.7	210.7	9.1	246.2	98.0	335.1
1940	26.7	198.3	13.9	212.2	9.5	240.2	99.8	330.5
1941	36.7	171.5	12.4	183.9	10.3	229.9	78.1	297.7
1942	30.3	171.9	12.9	184.8	11.5	246.3	77.1	311.9
1943	23.6	196.9	15.2	212.1	12.7	283.0	95.5	365.8
1944	18.9	211.0	16.1	227.1	13.8	297.7	106.1	390.0
1945	20.6	205.5	15.8	221.3	14.3	301.1	101.1	387.9
1946	18.4	218.1	16.5	234.6	15.5	326.1	109.3	419.9
1947	15.4	225.3	17.9	243.2	16.7	350.7	113.7	447.7
1948	20.1	183.2	14.4	197.6	17.9	312.9	80.8	375.8
1949	18.0	233.4	19.4	252.8	19.1	357.1	120.8	458.8
1950	17.9	231.8	19.6	251.4	19.8	337.6	121.7	439.5
1951	23.9	238.8	20.0	258.8	22.2	382.8	123.1	483.7
1952	30.4	232.5	20.0	252.5	23.8	331.2	123.2	430.6
1953	20.2	251.1	22.1	273.2	25.8	337.0	139.3	450.5
1954	18.1	242.0	21.6	263.6	27.4	406.1	124.6	503.3
1955	18.8	266.5	26.0	292.5	29.3	378.5	150.7	499.9
1956	29.4	264.9	28.1	293.0	31.0	331.1	155.8	455.9
1957	17.6	244.8	27.6	272.4	32.9	337.9	138.6	443.6
1958	30.5	237.6	28.7	266.3	34.6	347.4	132.7	445.5
1959	16.4	291.8	38.0	329.8	36.5	386.7	179.9	530.1
1960	13.6	296.0	40.9	336.9	38.8	397.8	184.5	543.5
1961	15.5	290.1	42.1	332.2	41.3	380.2	182.5	521.4
1962	19.2	305.7	44.5	350.2	43.7	392.6	159.0	507.9
1963	28.0	256.0	36.5	292.5	47.2	344.9	151.4	449.1
1964	15.7	310.1	45.8	355.9	50.4	429.5	174.2	553.3
1965	23.1	278.8	42.1	320.9	53.2	421.7	164.7	533.2
1966	13.6	316.2	48.4	364.6	56.3	495.0	182.0	620.7
1967	30.5	265.8	41.0	306.8	59.1	438.9	152.6	532.4
1968	14.9	298.1	46.5	344.6	62.3	535.6	202.5	675.8
1969	30.6	298.2	47.0	345.2	64.7	434.4	192.2	561.9
1970	20.3	313.6	48.5	362.1	68.2	486.2	190.1	608.1
1971	20.6	318.0	49.3	367.3	69.5	463.5	183.4	577.4
1972	13.7	287.9	50.2	338.1	71.8	518.9	223.3	670.4
1973	31.6	320.8	49.3	370.1	74.2	489.8	199.2	614.8
1974	27.7	325.5	46.2	371.7	76.5	509.7	207.0	640.2
1975	23.1	380.6	51.8	432.4	77.8	556.9	222.2	701.3
1976	10.5	376.4	56.1	432.5	80.2	546.3	262.0	728.1
1977	7.1	333.8	63.8	397.6	82.5	261.6	282.2	461.3
1978	31.9	295.3	56.9	352.2	84.5	479.5	188.7	583.7
1979	20.9	349.6	64.8	414.4	86.1	580.5	228.7	723.1
1980	28.4	376.2	63.5	439.7	88.5	577.5	249.4	738.4
AVG 22-80	21.3	244.4	27.8	272.2	32.6	343.0	137.9	448.3

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4H
WATER BUDGET FOR REGION 8 (DSA 59)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	19.0	261.4	7.7	269.1	19.1	93.0	262.5	336.4
1923	20.7	259.8	7.8	267.6	19.8	93.0	261.3	334.5
1924	8.4	313.3	9.0	322.3	20.3	61.0	362.2	402.9
1925	21.7	254.8	7.8	262.6	21.4	92.0	257.7	328.3
1926	14.9	302.4	9.3	311.7	22.2	71.8	340.0	389.6
1927	19.0	312.3	9.6	321.9	22.7	94.0	331.1	402.4
1928	14.6	327.0	9.7	336.7	23.4	89.1	355.2	420.9
1929	11.9	370.6	11.1	381.7	24.6	106.7	395.0	477.1
1930	13.7	369.9	11.5	381.4	25.0	118.8	383.0	476.8
1931	10.8	396.2	12.1	408.3	25.8	124.6	411.6	510.4
1932	16.6	384.7	12.5	397.2	26.2	129.5	393.2	496.5
1933	10.9	395.8	13.1	408.9	27.0	153.1	385.0	511.1
1934	12.2	399.0	13.6	412.6	27.4	156.5	386.7	515.8
1935	18.9	347.8	11.9	359.7	28.2	139.9	337.9	449.6
1936	20.4	364.0	13.1	377.1	29.3	142.2	358.5	471.4
1937	21.4	372.3	13.8	386.1	29.4	156.3	355.7	482.6
1938	23.6	374.1	13.7	387.8	30.5	144.1	371.2	484.8
1939	12.0	394.7	14.1	408.8	30.6	160.0	381.6	511.0
1940	19.7	401.6	15.3	416.9	31.7	155.8	397.0	521.1
1941	23.2	377.1	14.2	391.3	32.9	158.1	363.9	489.1
1942	21.7	365.4	13.8	379.2	34.2	154.8	353.4	474.0
1943	20.1	408.8	15.6	424.4	36.5	172.0	395.0	530.5
1944	15.3	432.2	17.3	449.5	37.7	191.1	408.5	561.9
1945	15.8	431.6	17.2	448.8	40.0	185.6	415.4	561.0
1946	15.2	441.7	17.7	459.4	41.3	198.4	417.2	574.3
1947	10.1	495.7	19.7	515.4	42.5	194.6	492.2	644.3
1948	15.7	413.7	17.2	430.9	44.8	182.0	401.4	538.6
1949	13.7	483.4	21.1	504.5	46.0	202.1	474.5	630.6
1950	14.8	473.0	21.6	494.6	48.0	224.3	442.0	618.3
1951	22.2	478.3	21.8	500.1	49.6	183.8	490.9	625.1
1952	22.4	482.1	22.8	504.9	50.8	189.7	492.2	631.1
1953	14.5	522.8	25.5	548.3	52.7	221.7	516.4	685.4
1954	12.6	519.4	25.1	544.5	53.9	218.2	516.3	680.6
1955	16.6	548.7	27.6	576.3	55.6	179.0	597.0	720.4
1956	22.6	563.0	28.4	591.4	57.5	208.0	588.8	739.3
1957	14.6	534.5	26.2	560.7	58.7	189.4	570.2	700.9
1958	28.6	517.0	25.7	542.7	60.3	197.4	541.3	678.4
1959	13.5	630.7	32.3	663.0	62.3	182.6	708.5	828.8
1960	11.1	667.9	34.1	702.0	63.5	187.7	753.3	877.5
1961	13.1	649.5	34.7	684.2	63.9	135.5	783.7	855.3
1962	15.3	680.0	37.2	717.2	64.6	192.6	616.8	744.8
1963	21.0	564.8	29.3	594.1	64.6	187.5	612.0	734.9
1964	12.3	685.2	37.1	722.3	64.7	166.1	630.4	731.8
1965	19.9	630.1	35.9	666.0	64.7	193.8	634.9	764.0
1966	12.8	725.1	41.8	766.9	65.8	224.0	643.2	801.4
1967	25.5	611.3	35.8	647.1	65.8	210.6	639.5	784.3
1968	12.2	688.6	41.0	729.6	65.9	238.3	694.9	867.3
1969	25.5	667.0	41.8	708.8	65.9	244.9	651.9	830.9
1970	17.3	684.8	43.1	727.9	67.0	256.1	707.2	896.3
1971	17.5	696.0	43.8	739.8	68.2	240.2	716.8	888.8
1972	10.1	738.8	46.9	785.7	69.4	239.9	765.7	936.2
1973	22.1	683.7	46.2	729.9	70.6	237.3	761.7	928.4
1974	21.3	603.3	42.2	645.5	71.8	226.2	790.1	944.5
1975	16.2	652.2	48.6	700.8	74.2	235.1	823.8	984.7
1976	7.9	776.7	55.2	831.9	75.4	204.2	905.3	1034.1
1977	7.5	760.7	59.5	820.2	76.6	171.3	942.8	1037.5
1978	25.6	590.0	52.4	642.4	77.8	184.2	696.6	803.0
1979	17.3	654.6	60.0	714.6	79.0	216.3	756.0	893.3
1980	20.7	631.7	59.4	691.1	80.9	211.9	732.9	863.9
AVG 22-80	16.9	504.5	26.3	530.8	48.3	174.9	528.3	654.9

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4I
WATER BUDGET FOR REGION 9 (DSA 55)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	13.6	502.5	9.7	512.2	8.6	233.7	620.0	845.1
1923	14.2	489.5	9.6	499.1	8.9	211.8	620.0	822.9
1924	6.1	526.5	10.3	536.8	9.2	274.7	620.0	885.5
1925	15.5	406.1	8.7	414.8	9.6	71.3	620.0	681.7
1926	11.7	483.4	9.8	493.2	9.9	202.0	620.0	812.1
1927	14.2	464.8	9.6	474.4	10.2	170.7	620.0	780.5
1928	11.2	503.6	9.8	513.4	10.5	235.7	620.0	845.2
1929	8.9	517.9	10.6	528.5	10.9	260.8	620.0	869.9
1930	11.0	556.2	10.3	566.5	11.2	324.2	620.0	933.0
1931	8.1	560.8	10.3	571.1	11.3	331.8	620.0	940.5
1932	13.2	571.9	10.7	582.6	11.3	351.0	620.0	959.7
1933	8.4	573.0	10.8	583.8	11.4	353.0	620.0	961.6
1934	9.3	569.7	10.8	580.5	11.5	347.5	620.0	956.0
1935	14.3	534.5	9.6	544.1	11.6	286.8	620.0	895.2
1936	13.8	512.8	9.8	522.6	11.7	251.0	620.0	859.3
1937	15.7	546.5	10.2	556.7	11.7	307.8	620.0	916.1
1938	18.5	535.4	10.2	545.6	11.8	289.3	620.0	897.5
1939	7.4	567.5	10.5	578.0	11.9	343.3	620.0	951.4
1940	17.1	547.1	10.3	557.4	11.9	309.0	620.0	917.1
1941	21.0	523.5	9.9	533.4	12.1	269.0	620.0	876.9
1942	16.9	524.7	9.9	534.6	12.2	271.0	620.0	878.8
1943	14.6	567.7	10.5	578.2	12.4	343.7	620.0	951.3
1944	12.1	572.8	11.2	584.0	12.5	353.3	620.0	960.8
1945	12.6	598.2	11.1	609.3	12.7	395.5	620.0	1002.8
1946	11.0	608.4	11.4	619.8	12.8	413.0	620.0	1020.2
1947	9.0	644.0	11.6	655.6	13.0	472.7	620.0	1079.7
1948	10.9	592.6	10.4	603.0	13.1	385.0	620.0	991.9
1949	10.1	666.8	12.8	679.6	13.3	512.7	620.0	1119.4
1950	9.9	686.4	14.2	700.6	13.4	547.7	620.0	1154.3
1951	15.3	652.9	13.6	666.5	13.9	490.8	620.0	1096.9
1952	18.2	662.3	13.4	675.7	14.3	506.2	620.0	1111.9
1953	11.7	690.5	14.2	704.7	14.7	554.5	620.0	1159.8
1954	9.3	705.9	13.6	719.5	15.2	579.2	620.0	1184.0
1955	12.7	693.9	14.0	707.9	15.6	559.8	620.0	1164.2
1956	18.6	681.1	14.1	695.2	16.1	538.7	620.0	1142.6
1957	10.7	651.5	12.4	663.9	16.5	486.5	620.0	1090.0
1958	22.4	589.6	11.0	600.6	16.9	381.0	620.0	984.1
1959	10.4	835.9	15.8	851.7	17.4	799.5	620.0	1402.1
1960	8.1	813.5	15.5	829.0	17.8	761.7	620.0	1363.9
1961	10.6	709.4	14.2	723.6	18.0	586.0	620.0	1188.0
1962	11.9	663.8	13.7	677.5	18.1	509.2	620.0	1111.1
1963	17.7	540.2	10.4	550.6	18.3	297.7	620.0	899.4
1964	8.5	741.4	15.6	757.0	18.4	641.7	620.0	1243.3
1965	14.5	600.8	13.4	614.2	18.6	403.7	620.0	1005.1
1966	9.7	690.0	16.5	706.5	18.7	557.5	620.0	1158.8
1967	19.7	558.6	13.1	571.7	18.8	332.8	620.0	934.0
1968	11.4	701.7	17.3	719.0	19.0	578.3	620.0	1179.3
1969	18.5	651.0	17.2	668.2	19.1	493.7	620.0	1094.6
1970	12.9	693.1	19.3	712.4	19.3	567.3	620.0	1168.0
1971	13.8	615.9	18.3	634.2	19.9	437.0	620.0	1037.1
1972	7.0	705.4	19.7	725.1	20.6	588.5	620.0	1187.9
1973	20.7	663.7	19.3	683.0	21.2	518.3	620.0	1117.1
1974	15.8	658.0	19.8	677.8	21.8	509.7	620.0	1107.9
1975	12.9	617.3	20.7	638.0	22.5	443.3	620.0	1040.8
1976	6.4	834.0	26.1	860.1	23.1	813.5	620.0	1410.4
1977	7.3	660.6	22.6	683.2	23.8	518.7	620.0	1114.9
1978	19.6	598.5	22.1	620.6	24.4	414.3	620.0	1009.9
1979	13.2	661.6	25.9	687.5	25.1	525.8	620.0	1120.7
1980	17.3	543.8	23.2	567.0	25.7	325.0	620.0	919.3
AVG 22-80	13.0	610.9	13.7	624.6	15.3	421.0	620.0	1025.7

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4J
WATER BUDGET FOR REGION 10 (DSA 49A)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.0	320.1	0.9	321.0	1.2	776.2	123.9	898.9
1923	11.3	347.5	1.2	348.7	2.3	793.0	153.7	944.4
1924	4.7	415.0	1.2	416.2	2.3	463.1	292.2	753.0
1925	13.4	322.4	0.9	323.3	2.3	735.3	133.9	866.9
1926	8.0	394.1	1.2	395.3	2.4	662.5	232.0	892.1
1927	11.0	370.9	1.3	372.2	2.4	785.1	182.9	965.6
1928	9.4	396.1	1.4	397.5	2.4	706.1	226.9	930.6
1929	9.2	430.6	1.5	432.1	2.4	710.8	267.0	975.4
1930	7.3	445.9	1.6	447.5	2.4	725.3	282.6	1005.5
1931	7.5	417.3	1.7	419.0	2.4	519.6	285.5	802.7
1932	10.5	384.5	1.7	386.2	2.4	789.8	198.6	986.0
1933	7.4	446.4	1.7	448.1	2.4	791.9	271.5	1061.0
1934	7.5	440.7	1.8	442.5	2.4	594.7	299.9	892.2
1935	16.8	357.5	1.6	359.1	2.4	825.1	160.3	983.0
1936	13.6	440.7	1.7	442.4	2.4	884.5	248.3	1130.4
1937	13.6	522.4	1.7	524.1	2.4	859.2	349.5	1206.3
1938	16.5	432.7	1.7	434.4	2.4	901.7	235.8	1135.1
1939	9.0	517.3	2.0	519.3	2.4	737.5	365.4	1100.5
1940	12.1	478.0	1.8	479.8	3.1	800.4	307.5	1104.8
1941	17.7	448.4	1.8	450.2	3.5	811.3	270.5	1078.3
1942	13.9	476.1	2.1	478.2	3.6	898.7	288.1	1183.2
1943	10.4	503.4	2.3	505.7	3.6	906.8	319.2	1222.4
1944	10.0	526.9	2.4	529.3	3.6	1016.6	327.6	1340.6
1945	11.7	509.1	2.4	511.5	3.6	1095.8	292.5	1384.7
1946	9.7	557.2	2.7	559.9	3.6	1080.9	352.4	1429.7
1947	6.9	649.8	2.9	652.7	4.7	953.0	484.9	1433.2
1948	11.0	610.7	2.6	613.3	4.7	910.3	445.9	1351.5
1949	8.1	738.7	3.2	741.9	4.8	956.2	589.9	1541.3
1950	9.7	621.6	3.2	624.8	4.8	915.4	458.6	1369.2
1951	12.3	743.7	3.2	746.9	4.8	918.2	602.6	1516.0
1952	15.5	693.7	3.2	696.9	4.8	959.6	536.1	1490.9
1953	9.1	817.4	3.6	821.0	4.8	1040.0	668.6	1703.8
1954	8.8	794.4	3.6	798.0	4.8	1119.9	627.2	1742.3
1955	10.2	686.5	3.9	690.4	5.5	1123.8	499.2	1617.5
1956	14.6	646.9	3.8	650.7	5.5	1122.9	452.4	1569.8
1957	7.8	708.0	4.1	712.1	5.9	1227.3	506.4	1727.8
1958	21.5	558.1	3.5	561.6	5.9	1032.8	363.0	1389.9
1959	8.4	738.5	4.3	742.8	5.9	1333.7	523.8	1851.6
1960	6.7	761.2	4.5	765.7	6.0	1355.1	547.1	1896.2
1961	8.6	736.3	4.4	740.7	6.0	1435.0	503.3	1932.3
1962	11.3	696.0	4.5	700.5	6.0	1264.8	464.9	1723.7
1963	11.4	666.8	4.3	671.1	6.0	1221.3	435.7	1651.0
1964	7.8	756.7	4.9	761.6	6.0	1400.6	514.2	1908.8
1965	11.1	688.9	4.8	693.7	6.0	1319.4	473.7	1787.1
1966	8.6	747.2	5.3	752.5	6.7	1441.8	542.8	1977.9
1967	15.3	611.8	4.6	616.4	6.7	1322.9	426.6	1742.8
1968	7.8	775.6	5.1	780.7	7.1	1466.2	505.4	1964.5
1969	19.8	666.8	5.0	671.8	7.1	1320.5	438.5	1751.9
1970	10.5	750.4	5.4	755.8	7.1	1463.0	508.0	1963.9
1971	10.4	772.6	5.4	778.0	7.2	1463.7	550.3	2006.8
1972	5.3	918.8	6.1	924.9	7.2	1623.1	652.5	2268.4
1973	16.2	725.9	5.4	731.3	7.9	1340.2	509.2	1841.5
1974	12.8	755.9	5.6	761.5	8.3	1542.7	482.1	2016.5
1975	10.8	746.2	6.0	752.2	8.3	1490.4	488.5	1970.6
1976	7.0	838.7	6.4	845.1	8.4	1644.7	672.8	2309.1
1977	5.5	904.1	6.9	911.0	8.4	1032.3	799.4	1823.3
1978	19.8	649.6	6.0	655.6	9.1	1149.3	453.5	1593.7
1979	12.0	735.1	6.9	742.0	9.5	1514.1	490.8	1995.4
1980	13.1	715.2	7.1	722.3	9.5	1469.5	475.4	1935.4
AVG 22-80	11.1	602.2	3.4	605.6	4.9	1063.8	409.5	1468.5

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

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TABLE 3.4K
WATER BUDGET FOR REGION 11 (DSA 49B)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.0	226.5	2.7	229.2	5.5	622.8	32.1	649.4
1923	11.3	236.1	3.1	239.2	5.9	694.4	20.2	708.7
1924	4.7	279.4	3.5	282.9	5.9	449.4	112.9	556.4
1925	13.4	219.2	3.1	222.3	6.0	626.4	24.8	645.2
1926	8.0	267.9	3.8	271.7	6.0	576.4	77.1	647.5
1927	11.0	257.0	4.1	261.1	6.0	721.4	32.4	747.8
1928	9.4	267.6	4.2	271.8	6.7	620.5	66.8	680.6
1929	9.2	273.5	4.4	277.9	7.1	662.3	61.3	716.5
1930	7.3	289.8	5.0	294.8	7.1	693.5	66.5	752.9
1931	7.5	290.5	5.0	295.5	7.2	466.5	117.6	576.9
1932	10.5	286.3	5.3	291.6	7.2	812.6	33.5	838.9
1933	7.4	311.4	5.6	317.0	7.9	726.4	75.1	793.6
1934	7.5	314.2	5.6	319.8	8.3	636.2	97.4	725.3
1935	16.8	266.5	4.9	271.4	8.3	695.5	47.9	735.1
1936	13.6	295.4	5.4	300.8	8.3	776.5	50.7	818.9
1937	13.6	303.9	5.3	309.2	8.4	706.0	74.2	771.8
1938	16.5	309.4	5.7	315.1	9.1	768.1	63.8	822.8
1939	9.0	355.5	6.0	361.5	9.1	689.0	114.1	794.0
1940	12.1	355.9	6.1	362.0	9.5	777.0	95.5	863.0
1941	17.7	339.8	6.1	345.9	9.6	775.0	84.7	850.1
1942	13.9	351.4	6.1	357.5	10.7	812.4	84.4	886.1
1943	10.4	391.3	7.0	398.3	10.7	810.1	112.8	912.2
1944	10.0	415.7	7.7	423.4	11.5	840.7	122.9	952.1
1945	11.7	407.4	7.5	414.9	11.9	867.9	111.6	967.6
1946	9.7	437.1	8.2	445.3	12.7	848.1	135.5	970.9
1947	6.9	485.8	9.1	494.9	13.1	727.8	189.5	904.2
1948	11.0	428.2	8.2	436.4	13.9	744.7	150.7	881.5
1949	8.1	500.7	9.5	510.2	14.3	782.0	188.3	956.0
1950	9.7	489.2	9.8	499.0	15.0	866.4	165.3	1016.7
1951	12.3	490.5	9.9	500.4	15.1	839.3	171.4	995.6
1952	15.5	485.5	9.9	495.4	15.5	908.1	154.9	1047.5
1953	9.1	583.9	11.3	595.2	15.5	946.0	207.3	1137.8
1954	8.8	599.1	11.1	610.2	16.2	868.0	230.2	1082.0
1955	10.2	560.4	11.8	572.2	16.7	787.0	223.3	993.6
1956	14.6	555.7	12.0	567.7	16.7	972.9	186.1	1142.3
1957	7.8	593.5	12.3	605.8	17.4	924.9	217.3	1124.8
1958	21.5	491.0	10.8	501.8	17.4	929.2	154.7	1066.5
1959	8.4	620.3	13.3	633.6	17.9	863.6	244.2	1089.9
1960	6.7	650.1	13.8	663.9	17.9	854.5	262.6	1099.2
1961	8.6	629.9	13.8	643.7	18.6	689.4	280.4	951.2
1962	11.3	626.0	14.4	640.4	19.0	1024.9	223.1	1229.0
1963	11.4	587.8	13.3	601.1	19.1	924.2	209.1	1114.2
1964	7.8	655.6	14.7	670.3	19.8	910.1	246.8	1137.1
1965	11.1	620.7	14.6	635.3	19.8	1023.6	227.4	1231.2
1966	8.6	677.8	16.1	693.9	20.3	865.8	260.5	1106.0
1967	15.3	572.9	14.3	587.2	21.0	911.2	204.7	1094.9
1968	7.8	684.4	16.3	700.7	21.0	869.6	242.6	1091.2
1969	19.8	617.2	15.4	632.6	21.4	1005.9	210.5	1195.0
1970	10.5	664.2	16.4	680.6	21.5	1028.6	243.8	1250.9
1971	10.4	680.2	16.9	697.1	22.2	994.7	264.1	1236.6
1972	5.3	779.7	18.7	798.4	23.4	922.0	313.2	1211.8
1973	16.2	645.6	17.1	662.7	23.8	946.0	244.4	1166.6
1974	12.8	625.5	17.4	642.9	24.6	963.5	231.4	1170.3
1975	10.8	643.7	18.0	661.7	25.8	1087.5	234.5	1296.2
1976	7.0	687.8	19.7	707.5	26.2	866.7	323.0	1163.5
1977	5.5	692.4	21.2	713.6	27.0	418.5	383.7	775.2
1978	19.8	524.2	18.5	542.7	28.1	854.9	193.7	1020.5
1979	12.0	589.9	21.5	611.4	28.2	1066.1	194.3	1232.2
1980	13.1	566.0	21.6	587.6	29.3	1073.9	178.7	1223.3
AVG 22-80	11.1	475.5	10.6	486.1	15.1	815.9	162.2	963.0

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4L
WATER BUDGET FOR REGION 12 (DSA 49C)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.0	201.5	1.3	202.8	2.4	408.9	47.4	453.9
1923	11.3	213.2	1.3	214.5	2.4	478.5	48.6	524.7
1924	4.7	260.1	1.6	261.7	2.4	437.3	77.1	512.0
1925	13.4	198.3	1.5	199.8	2.4	475.6	40.8	514.0
1926	8.0	244.3	1.7	246.0	2.4	490.3	64.7	552.6
1927	11.0	227.2	1.8	229.0	2.4	493.2	55.3	546.1
1928	9.4	242.0	1.8	243.8	3.1	528.6	60.7	586.2
1929	9.2	247.6	1.9	249.5	3.5	489.9	66.6	553.0
1930	7.3	263.6	2.5	266.1	3.5	491.7	75.5	563.7
1931	7.5	267.0	2.3	269.3	3.6	410.5	83.2	490.1
1932	10.5	251.3	2.4	253.7	3.6	561.2	63.6	621.2
1933	7.4	277.1	2.5	279.6	3.6	536.5	79.4	612.3
1934	7.5	282.1	2.5	284.6	3.6	511.3	84.0	591.7
1935	16.8	230.3	2.2	232.5	3.6	526.5	54.7	577.6
1936	13.6	249.4	2.4	251.8	3.6	524.2	65.3	585.9
1937	13.6	254.3	2.5	256.8	3.6	516.4	68.6	581.4
1938	16.5	258.5	2.5	261.0	3.6	449.0	75.9	521.3
1939	9.0	302.2	2.8	305.0	4.3	561.5	91.3	648.5
1940	12.1	289.4	2.8	292.2	4.3	575.4	83.3	654.4
1941	17.7	272.8	2.8	275.6	4.7	534.3	77.4	607.0
1942	13.9	278.1	2.8	280.9	4.8	581.9	76.8	653.9
1943	10.4	314.8	3.1	317.9	4.8	600.0	95.4	690.6
1944	10.0	330.9	3.4	334.3	4.8	651.4	100.4	747.0
1945	11.7	318.7	3.5	322.2	5.9	626.6	95.7	716.4
1946	9.7	342.6	3.7	346.3	5.9	629.8	108.5	732.4
1947	6.9	379.8	4.1	383.9	6.0	570.6	133.3	697.9
1948	11.0	330.7	3.7	334.4	6.0	530.7	109.5	634.2
1949	8.1	376.4	4.3	380.7	6.7	616.0	128.1	737.4
1950	9.7	366.4	4.4	370.8	7.1	628.0	121.9	742.8
1951	12.3	355.4	4.6	360.0	7.1	580.4	119.6	692.9
1952	15.5	342.0	4.6	346.6	7.1	592.0	111.5	696.4
1953	9.1	406.6	5.1	411.7	7.2	674.6	140.5	807.9
1954	8.8	412.0	5.0	417.0	7.2	642.9	145.8	781.5
1955	10.2	392.0	5.4	397.4	7.2	584.3	139.5	716.6
1956	14.6	385.1	5.4	390.5	7.9	651.7	130.8	774.6
1957	7.8	428.1	5.6	433.7	7.9	643.0	154.8	789.9
1958	21.5	340.3	4.8	345.1	8.3	559.6	113.1	664.4
1959	8.4	444.3	6.0	450.3	8.3	547.7	170.8	710.2
1960	6.7	470.6	6.5	477.1	8.3	556.1	184.7	732.5
1961	8.6	456.9	6.2	463.1	8.3	440.1	185.8	617.6
1962	11.3	447.2	6.5	453.7	8.4	712.6	167.3	871.5
1963	11.4	427.4	6.2	433.6	8.4	643.8	156.9	792.3
1964	7.8	485.7	6.7	492.4	9.1	597.6	185.1	773.6
1965	11.1	452.1	6.5	458.6	9.1	720.1	170.5	881.5
1966	8.6	499.0	7.3	506.3	9.5	585.0	195.4	770.9
1967	15.3	415.2	6.6	421.8	9.5	702.9	153.6	847.0
1968	7.8	518.7	7.5	526.2	9.5	594.5	181.9	766.9
1969	19.8	457.4	7.0	464.4	9.5	681.2	157.9	829.6
1970	10.5	502.7	7.6	510.3	9.6	719.5	182.9	892.8
1971	10.4	517.6	7.6	525.2	10.3	687.9	198.1	875.7
1972	5.3	615.4	8.5	623.9	10.7	692.0	234.9	916.2
1973	16.2	491.9	7.8	499.7	10.7	677.2	183.3	849.8
1974	12.8	474.4	7.8	482.2	11.5	712.3	173.6	874.4
1975	10.8	493.5	8.3	501.8	11.9	779.6	175.9	943.6
1976	7.0	555.0	9.0	564.0	11.9	886.5	242.2	1116.8
1977	5.5	575.3	9.7	585.0	11.9	283.1	287.8	559.0
1978	19.8	421.4	8.3	429.7	12.7	602.9	155.6	745.8
1979	12.0	480.9	9.8	490.7	13.1	741.9	178.2	907.0
1980	13.1	464.1	9.7	473.8	13.1	757.3	167.9	912.1
AVG 22-80	11.1	369.5	4.8	374.3	6.8	587.9	126.8	707.8

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4M
WATER BUDGET FOR REGION 13 (DSA 49D)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	15.0	499.0	2.6	501.6	4.8	572.1	557.2	1124.5
1923	11.3	532.6	2.9	535.5	5.5	515.3	616.0	1125.8
1924	4.7	638.3	3.4	641.7	5.9	226.9	851.5	1072.5
1925	13.4	505.6	3.1	508.7	5.9	470.4	611.5	1076.0
1926	8.0	618.5	3.5	622.0	6.0	454.5	726.5	1175.0
1927	11.0	591.5	3.8	595.3	6.0	564.7	649.7	1208.4
1928	9.4	629.9	4.0	633.9	6.0	514.8	709.7	1218.5
1929	9.2	664.5	4.3	668.8	6.0	459.0	768.9	1221.9
1930	7.3	701.5	4.7	706.2	6.7	463.6	802.2	1259.1
1931	7.5	681.9	4.8	686.7	7.1	228.4	893.5	1114.8
1932	10.5	644.3	4.9	649.2	7.1	604.3	682.4	1279.6
1933	7.4	721.0	5.1	726.1	7.2	502.3	803.1	1298.2
1934	7.5	719.5	5.3	724.8	7.2	322.2	885.9	1200.9
1935	16.8	592.2	4.5	596.7	7.9	536.4	664.2	1192.7
1936	13.6	677.6	5.1	682.7	8.3	537.4	745.4	1274.5
1937	13.6	739.1	5.1	744.2	8.3	560.5	793.1	1345.3
1938	16.5	685.6	5.3	690.9	8.3	593.0	727.3	1312.0
1939	9.0	798.7	5.6	804.3	8.4	475.1	890.0	1356.7
1940	12.1	765.7	5.6	771.3	8.4	567.6	815.5	1374.7
1941	17.7	724.8	5.7	730.5	9.5	554.9	782.7	1328.1
1942	13.9	758.8	6.0	764.8	9.6	549.0	818.0	1357.4
1943	10.4	827.9	6.5	834.4	10.7	572.4	873.2	1434.9
1944	10.0	877.0	7.2	884.2	10.7	653.5	882.6	1525.4
1945	11.7	852.7	7.3	860.0	11.5	735.4	821.4	1545.3
1946	9.7	922.9	7.7	930.6	11.9	729.6	891.1	1608.8
1947	6.9	1043.5	8.6	1052.1	12.7	634.1	1051.1	1672.5
1948	11.0	951.0	7.6	958.6	13.1	626.1	966.0	1579.0
1949	8.1	1112.2	9.1	1121.3	13.1	751.9	1061.8	1800.6
1950	9.7	1018.5	9.2	1027.7	14.3	729.2	983.5	1698.4
1951	12.3	1089.4	9.4	1098.8	14.3	657.3	1084.6	1727.6
1952	15.5	1041.8	9.3	1051.1	14.3	827.0	960.1	1772.8
1953	9.1	1219.8	10.7	1230.5	15.0	748.7	1167.0	1900.7
1954	8.8	1213.3	10.6	1223.9	15.5	810.0	1132.1	1926.6
1955	10.2	1124.9	11.1	1136.0	15.5	743.2	1079.8	1807.5
1956	14.6	1084.4	11.5	1095.9	16.2	914.2	961.9	1859.9
1957	7.8	1178.3	11.8	1190.1	16.2	921.3	1048.0	1953.1
1958	21.5	933.3	10.0	943.3	16.7	846.7	848.5	1678.5
1959	8.4	1216.8	12.5	1229.3	16.7	789.9	1146.6	1919.8
1960	6.7	1272.4	13.3	1285.7	17.4	670.2	1256.1	1908.9
1961	8.6	1228.4	13.0	1241.4	17.4	448.0	1317.8	1748.4
1962	11.3	1190.8	13.7	1204.5	17.9	982.7	1004.1	1968.9
1963	11.4	1134.7	12.6	1147.3	17.9	947.6	941.1	1870.8
1964	7.8	1280.5	13.8	1294.3	18.6	771.5	1110.6	1863.5
1965	11.1	1186.4	13.9	1200.3	18.6	1070.0	1023.2	2074.6
1966	8.6	1294.3	15.3	1309.6	19.1	642.1	1172.4	1795.4
1967	15.3	1076.0	13.4	1089.4	19.8	1143.0	921.3	2044.5
1968	7.8	1334.2	15.3	1349.5	19.8	852.5	1091.6	1924.3
1969	19.8	1172.3	14.6	1186.9	20.2	1160.6	947.2	2087.6
1970	10.5	1292.8	15.5	1308.3	20.3	1030.5	1097.2	2107.4
1971	10.4	1329.4	16.0	1345.4	21.0	920.0	1188.6	2087.6
1972	5.3	1555.3	17.6	1572.9	22.2	855.4	1409.3	2242.5
1973	16.2	1240.1	16.1	1256.2	22.6	1071.7	1099.8	2148.9
1974	12.8	1244.7	16.4	1261.1	23.4	1188.5	1041.4	2206.5
1975	10.8	1247.9	17.0	1264.9	23.8	1096.4	1055.1	2127.7
1976	7.0	1369.8	18.8	1388.6	24.6	719.0	1453.3	2147.7
1977	5.5	1437.9	20.1	1458.0	25.8	291.9	1726.7	1992.8
1978	19.8	1045.3	17.4	1062.7	26.2	1168.8	811.5	1954.1
1979	12.0	1198.9	20.3	1219.2	27.0	1206.1	942.7	2121.8
1980	13.1	1163.2	20.4	1183.6	27.4	1301.7	864.2	2138.5
AVG 22-80	11.1	981.2	10.0	991.2	14.2	720.4	953.0	1659.2

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4N
WATER BUDGET FOR REGION 14 (DSA 60A)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	387.7	1.4	389.1	1.9	0.0	457.8	455.9
1923	8.0	424.3	1.4	425.7	2.3	0.0	500.8	498.5
1924	4.2	441.6	1.6	443.2	2.3	0.0	521.5	519.2
1925	7.9	426.1	1.6	427.7	2.3	0.0	503.2	500.9
1926	6.6	441.7	1.7	443.4	2.4	0.0	521.6	519.2
1927	9.7	407.0	1.6	408.6	2.4	0.0	480.6	478.2
1928	6.8	452.0	1.6	453.6	2.4	0.0	533.6	531.2
1929	6.4	454.9	1.8	456.7	2.4	0.0	537.4	535.0
1930	5.9	439.4	1.7	441.1	2.4	0.0	518.9	516.5
1931	6.7	427.5	1.9	429.4	2.4	0.0	505.2	502.8
1932	9.2	392.8	1.8	394.6	2.4	0.0	464.3	461.9
1933	6.3	416.9	1.8	418.7	2.4	0.0	492.6	490.2
1934	3.1	442.6	2.0	444.6	2.4	0.0	523.1	520.7
1935	12.5	334.7	1.8	336.5	2.4	0.0	395.8	393.4
1936	8.1	375.1	2.1	377.2	2.4	0.0	443.8	441.4
1937	11.5	334.2	2.2	336.4	2.4	0.0	395.7	393.3
1938	13.1	301.1	2.1	303.2	2.4	0.0	356.7	354.3
1939	7.3	359.5	2.4	361.9	2.4	0.0	425.8	423.4
1940	8.8	357.7	2.5	360.2	3.1	0.0	423.8	420.7
1941	13.9	324.9	2.3	327.2	3.5	0.0	385.0	381.5
1942	7.8	422.5	2.6	425.1	3.6	0.0	500.1	496.5
1943	9.4	412.1	2.6	414.7	3.6	0.0	488.0	484.4
1944	6.4	475.0	3.0	478.0	3.6	0.0	562.3	558.7
1945	8.8	485.3	3.1	488.4	3.6	0.0	574.7	571.1
1946	7.1	548.2	3.2	551.4	3.6	0.0	648.7	645.1
1947	5.9	608.2	3.4	611.6	3.6	0.0	719.5	715.9
1948	5.5	605.6	3.4	609.0	4.3	0.0	716.3	712.0
1949	5.0	666.5	3.7	670.2	4.7	0.0	788.4	783.7
1950	6.0	683.6	3.7	687.3	4.7	0.0	808.5	803.8
1951	6.1	705.4	3.7	709.1	4.8	0.0	834.2	829.4
1952	10.4	621.7	3.6	625.3	4.8	0.0	735.6	730.8
1953	7.1	711.9	4.0	715.9	4.8	0.0	842.1	837.3
1954	6.4	731.0	4.1	735.1	4.8	0.0	864.8	860.0
1955	7.5	759.3	4.1	763.4	4.8	0.0	898.1	893.3
1956	8.0	799.9	4.3	804.2	4.8	0.0	946.1	941.3
1957	5.7	903.0	4.4	907.4	5.5	0.0	1067.3	1061.8
1958	14.0	736.6	3.6	740.2	5.5	0.0	870.9	865.4
1959	3.9	1005.0	4.6	1009.6	5.9	0.0	1187.7	1181.8
1960	4.7	988.9	4.7	993.6	5.9	0.0	1168.9	1163.0
1961	5.5	1015.1	4.7	1019.8	5.9	0.0	1199.8	1193.9
1962	8.6	920.4	4.5	924.9	5.9	0.0	1088.1	1082.2
1963	8.0	919.7	4.4	924.1	6.0	0.0	1087.2	1081.2
1964	5.0	1022.6	4.5	1027.1	6.0	38.2	1170.0	1202.2
1965	7.6	989.7	4.5	994.2	6.0	34.1	1135.6	1163.7
1966	5.7	1061.0	4.8	1065.8	6.0	30.1	1223.9	1248.0
1967	10.6	910.2	4.3	914.5	6.0	20.1	1055.8	1069.9
1968	5.6	1066.5	4.8	1071.3	6.0	157.0	1103.4	1254.4
1969	15.6	829.6	4.4	834.0	6.0	250.1	731.1	975.2
1970	5.6	1079.8	4.9	1084.7	6.7	438.8	559.0	991.1
1971	6.9	1055.2	5.1	1060.3	6.7	599.1	463.0	1055.4
1972	3.6	1140.2	5.5	1145.7	7.1	840.0	465.0	1297.9
1973	9.3	1002.3	5.3	1007.6	7.1	763.7	172.0	928.6
1974	6.1	1125.8	6.0	1131.8	7.1	1075.0	209.0	1276.9
1975	7.0	1136.4	5.9	1142.3	7.2	1250.5	247.0	1490.3
1976	6.9	1107.1	6.2	1113.3	7.2	1285.1	233.0	1510.9
1977	4.6	1201.2	6.6	1207.8	7.2	407.9	637.0	1037.7
1978	15.8	860.9	6.0	866.9	7.9	667.5	247.0	906.6
1979	7.0	1172.6	7.2	1179.8	7.9	1075.5	202.0	1269.6
1980	8.4	1129.3	6.9	1136.2	8.3	1143.5	198.0	1333.2
AVG 22-80	7.7	704.4	3.6	708.0	4.6	170.8	644.7	810.9

SOURCES OF DATA---

RAIN:	CONSUMPTIVE USE MODEL (DWR)
CUAW:	CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE:	CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY:	USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING:	USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.40
WATER BUDGET FOR REGION 15 (DSA 69B)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	712.4	2.5	714.9	3.6	468.3	502.9	967.6
1923	8.0	766.4	2.8	769.2	3.6	315.0	648.1	959.5
1924	4.2	801.5	2.8	804.3	3.6	94.6	804.1	895.1
1925	7.9	772.6	2.9	775.5	3.6	272.1	674.7	943.2
1926	6.6	799.3	3.1	802.4	3.6	202.3	738.4	937.1
1927	9.7	741.4	3.0	744.4	3.6	375.4	598.8	970.6
1928	6.8	811.8	3.0	814.8	3.6	205.8	765.1	967.3
1929	6.4	821.3	3.2	824.5	3.6	288.0	712.1	996.5
1930	5.9	800.9	3.3	804.2	3.6	290.1	686.5	973.0
1931	6.7	777.8	3.4	781.2	3.6	141.7	749.8	887.9
1932	9.2	717.0	3.3	720.3	4.7	803.9	357.1	1156.3
1933	6.3	758.2	3.8	762.0	4.7	454.0	554.3	1003.6
1934	3.1	798.9	4.0	802.9	4.8	220.8	759.8	975.8
1935	12.5	614.6	3.4	618.0	4.8	680.0	337.0	1012.2
1936	8.1	682.9	4.0	686.9	4.8	768.6	380.6	1144.4
1937	11.5	610.8	3.8	614.6	4.8	971.4	272.4	1239.0
1938	13.1	561.8	3.9	565.7	4.8	1488.6	170.8	1654.6
1939	7.3	654.1	4.4	658.5	5.5	391.0	513.6	899.1
1940	8.8	658.6	4.3	662.9	5.9	781.8	356.2	1132.1
1941	13.9	604.9	4.2	609.1	5.9	1048.0	226.4	1268.5
1942	7.8	765.4	4.8	770.2	6.0	811.4	355.2	1160.6
1943	9.4	756.1	5.0	761.1	6.0	821.0	418.8	1233.8
1944	6.4	864.0	5.5	869.5	6.7	529.8	639.8	1162.9
1945	8.8	881.3	5.4	886.7	7.1	802.9	519.4	1315.2
1946	7.1	988.6	5.8	994.4	7.2	697.7	707.4	1397.9
1947	5.9	1092.2	6.3	1098.5	7.2	486.7	958.9	1438.4
1948	5.5	1103.4	6.2	1109.6	7.9	388.6	948.8	1329.5
1949	5.0	1211.9	6.8	1218.7	8.3	361.6	1074.1	1427.4
1950	6.0	1237.0	7.1	1244.1	8.3	506.8	1039.1	1537.6
1951	6.1	1271.5	7.1	1278.6	8.4	613.4	1147.7	1752.7
1952	10.4	1140.7	6.7	1147.4	9.1	1143.9	593.3	1728.1
1953	7.1	1287.4	7.3	1294.7	9.1	455.5	1139.0	1585.4
1954	6.4	1323.9	7.5	1331.4	9.5	550.7	1089.5	1630.7
1955	7.5	1345.0	7.8	1352.8	9.5	400.7	1182.8	1574.0
1956	8.0	1387.9	7.7	1395.6	9.5	1021.5	896.3	1908.3
1957	5.7	1524.1	7.9	1532.0	9.6	616.5	1246.3	1853.2
1958	14.0	1243.8	6.7	1250.5	10.3	926.3	765.1	1681.1
1959	3.9	1662.8	8.5	1671.3	10.3	611.0	1414.3	2015.0
1960	4.7	1636.6	8.4	1645.0	10.7	271.5	1564.2	1825.0
1961	5.5	1655.4	8.4	1663.8	10.7	247.9	1597.5	1834.7
1962	8.6	1513.8	8.2	1522.0	10.7	725.0	1403.0	2117.3
1963	8.0	1511.6	8.1	1519.7	10.7	803.0	1319.3	2111.6
1964	5.0	1657.1	8.4	1665.5	10.8	565.1	1534.2	2088.5
1965	7.6	1596.7	8.4	1605.1	11.5	847.4	1342.6	2178.5
1966	5.7	1700.7	8.9	1709.6	11.5	630.1	1490.3	2108.9
1967	10.6	1471.7	8.1	1479.8	11.5	1162.5	1156.6	2307.6
1968	5.6	1705.3	8.9	1714.2	11.9	582.8	1248.5	1819.4
1969	15.6	1352.2	8.1	1360.3	11.9	1029.7	1065.6	2083.4
1970	5.6	1718.1	9.2	1727.3	11.9	672.8	1170.2	1831.1
1971	6.9	1677.6	9.5	1687.1	11.9	640.1	1201.3	1829.5
1972	3.6	1802.8	10.3	1813.1	12.7	708.8	1295.7	1991.8
1973	9.3	1561.3	9.9	1571.2	13.1	966.6	1082.8	2036.3
1974	6.1	1705.3	10.8	1716.1	13.1	1207.5	996.9	2191.3
1975	7.0	1677.5	11.1	1688.6	13.1	1058.3	1043.3	2088.5
1976	6.9	1607.0	11.2	1618.2	13.9	669.1	1255.2	1910.4
1977	4.6	1716.8	12.3	1729.1	14.3	293.0	1594.5	1873.2
1978	15.8	1220.3	11.1	1231.4	14.3	895.5	781.8	1663.0
1979	7.0	1613.8	12.9	1626.7	14.3	1334.0	993.1	2312.8
1980	8.4	1525.4	13.0	1538.4	15.0	1525.0	831.9	2341.9
AVG 22-80	7.7	1172.6	6.7	1179.2	8.4	658.4	896.8	1546.8

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4P
WATER BUDGET FOR REGION 16 (DSA 60C)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	186.1	9.8	195.9	11.9	193.4	141.0	322.5
1923	8.0	197.5	10.1	207.6	12.7	278.0	119.0	384.3
1924	4.2	209.2	10.6	219.8	13.1	52.9	271.1	310.9
1925	7.9	199.7	10.7	210.4	13.1	245.6	130.2	362.7
1926	6.6	205.3	11.1	216.4	13.1	183.9	206.6	377.4
1927	9.7	191.8	10.9	202.7	13.9	332.8	91.9	410.8
1928	6.8	208.0	11.1	219.1	14.3	157.4	194.6	337.7
1929	6.4	212.5	11.6	224.1	14.3	349.1	96.4	431.2
1930	5.9	208.8	12.1	220.9	14.3	369.6	100.2	455.5
1931	6.7	202.1	12.3	214.4	15.5	234.3	158.3	377.1
1932	9.2	186.5	12.6	199.1	15.5	579.6	34.3	598.4
1933	6.3	198.5	13.7	212.2	16.3	432.8	59.9	476.4
1934	3.1	206.5	14.7	221.2	16.7	324.2	135.0	442.5
1935	12.5	159.9	12.9	172.8	17.4	450.3	45.1	478.0
1936	8.1	177.3	14.4	191.7	17.9	536.6	36.1	554.8
1937	11.5	158.7	14.0	172.7	18.6	511.9	37.7	531.0
1938	13.1	149.1	14.2	163.3	19.1	495.4	11.7	488.0
1939	7.3	170.3	16.1	186.4	19.8	377.6	77.1	434.9
1940	8.8	173.0	16.1	189.1	20.3	442.8	62.4	484.9
1941	13.9	161.2	16.0	177.2	21.4	475.7	19.5	473.8
1942	7.8	198.1	17.8	215.9	22.2	507.4	33.7	518.9
1943	9.4	196.7	18.3	215.0	23.4	468.1	53.8	498.5
1944	6.4	225.6	20.4	246.0	24.6	415.7	81.4	472.5
1945	8.8	227.8	20.1	247.9	25.8	526.7	45.2	546.1
1946	7.1	254.9	21.6	276.5	27.0	494.3	95.5	562.8
1947	5.9	281.3	22.8	304.1	28.1	385.2	169.1	526.2
1948	5.5	287.4	23.0	310.4	29.3	338.1	187.9	496.7
1949	5.0	316.7	25.0	341.7	30.5	331.5	221.2	522.2
1950	6.0	321.9	25.9	347.8	31.0	432.2	184.5	585.7
1951	6.1	328.8	26.2	355.0	31.8	479.1	186.1	633.4
1952	10.4	297.4	25.1	322.5	32.9	574.5	76.5	618.1
1953	7.1	333.7	27.2	360.9	33.4	440.2	188.3	595.1
1954	6.4	343.4	27.6	371.0	34.1	441.1	187.6	594.6
1955	7.5	356.9	28.3	385.2	35.3	424.3	207.7	596.7
1956	8.0	376.2	28.8	405.0	35.3	606.0	121.4	692.1
1957	5.7	415.8	29.3	445.1	36.5	430.3	279.5	673.3
1958	14.0	345.6	25.3	370.9	37.7	546.8	114.3	623.4
1959	3.9	464.1	31.4	495.5	37.7	393.3	382.7	738.3
1960	4.7	462.2	31.6	493.8	38.9	359.4	409.5	730.0
1961	5.5	463.8	31.1	494.9	39.6	288.8	469.6	718.8
1962	8.6	429.9	30.3	460.2	40.1	524.8	314.1	798.8
1963	8.0	431.2	29.8	461.0	40.1	522.4	295.4	777.7
1964	5.0	471.7	31.0	502.7	41.3	401.3	343.6	703.6
1965	7.6	453.9	30.8	484.7	41.3	596.9	300.8	856.4
1966	5.7	488.2	33.1	521.3	42.4	485.0	333.9	776.5
1967	10.6	421.6	29.8	451.4	42.5	636.4	258.9	852.8
1968	5.6	494.4	32.9	527.3	43.6	500.7	279.6	736.7
1969	15.6	408.8	30.6	439.4	43.7	565.6	238.8	760.7
1970	5.6	505.0	34.1	539.1	44.8	611.9	262.1	829.2
1971	6.9	491.0	34.7	525.7	45.6	557.4	269.2	781.0
1972	3.6	530.2	38.5	568.7	46.8	409.8	290.3	653.3
1973	9.3	453.3	36.5	489.8	47.3	597.8	242.5	793.0
1974	6.1	491.7	40.4	532.1	48.4	577.2	223.2	752.0
1975	7.0	473.0	41.4	514.4	49.6	596.7	233.7	780.8
1976	6.9	449.3	41.9	491.2	50.8	276.0	281.0	506.2
1977	4.6	473.4	45.1	518.5	52.0	242.5	357.0	547.5
1978	15.8	356.2	41.3	397.5	52.8	538.4	157.9	643.5
1979	7.0	437.5	47.8	485.3	53.9	532.2	259.4	737.7
1980	8.4	410.2	48.1	458.3	55.1	760.0	164.0	868.9
AVG 22-80	7.7	320.9	24.7	345.6	31.1	438.0	183.5	590.4

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4Q
WATER BUDGET FOR REGION 17 (DSA 60D)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	210.3	2.8	213.1	3.6	223.6	109.4	329.4
1923	8.0	224.9	3.0	227.9	3.6	173.6	160.0	330.0
1924	4.2	240.5	3.3	243.8	3.6	39.1	277.0	312.5
1925	7.9	227.7	3.0	230.7	3.6	167.4	166.9	330.7
1926	6.6	234.3	3.3	237.6	3.6	110.9	222.8	330.1
1927	9.7	217.0	3.2	220.2	3.6	208.2	126.4	331.0
1928	6.8	238.7	3.2	241.9	3.6	90.0	239.9	326.3
1929	6.4	243.1	3.3	246.4	4.3	195.9	202.0	393.6
1930	5.9	239.2	3.5	242.7	4.7	190.8	166.3	352.4
1931	6.7	231.4	3.5	234.9	4.7	64.5	250.2	310.0
1932	9.2	211.1	3.5	214.6	4.8	579.4	81.7	656.3
1933	6.3	226.7	4.1	230.8	4.8	267.1	155.6	417.9
1934	3.1	237.0	4.2	241.2	4.8	82.4	243.1	320.7
1935	12.5	179.9	3.8	183.7	4.8	463.0	115.7	573.9
1936	8.1	202.1	4.2	206.3	4.8	539.7	102.9	637.8
1937	11.5	178.7	4.1	182.8	5.5	610.3	82.2	687.0
1938	13.1	167.1	4.2	171.3	5.9	541.6	61.9	597.6
1939	7.3	194.4	4.6	199.0	5.9	234.8	148.1	377.0
1940	8.8	195.7	4.8	200.5	6.0	493.7	110.9	598.6
1941	13.9	180.7	4.6	185.3	6.0	525.8	72.5	592.3
1942	7.8	225.7	5.3	231.0	6.7	474.6	87.3	555.2
1943	9.4	223.5	5.4	228.9	7.1	446.0	110.6	549.5
1944	6.4	258.0	6.0	264.0	7.2	287.9	189.1	469.8
1945	8.8	259.0	5.8	264.8	7.2	492.0	110.3	595.1
1946	7.1	291.4	6.3	297.7	7.9	425.6	177.2	594.9
1947	5.9	322.6	6.7	329.3	8.3	248.0	277.4	517.1
1948	5.5	329.9	6.8	336.7	8.3	272.7	245.3	509.7
1949	5.0	363.9	7.3	371.2	8.4	276.3	283.6	551.5
1950	6.0	368.3	7.5	375.8	9.1	330.3	250.0	571.2
1951	6.1	376.2	7.6	383.8	9.5	373.7	246.4	610.6
1952	10.4	335.1	7.4	342.5	9.5	716.8	112.6	819.9
1953	7.1	380.8	7.9	388.7	9.6	331.8	256.6	578.8
1954	6.4	393.6	8.0	401.6	9.6	377.2	229.4	597.0
1955	7.5	409.0	8.3	417.3	10.3	275.5	320.5	585.7
1956	8.0	431.2	8.5	439.7	10.7	744.8	86.8	820.9
1957	5.7	483.0	8.7	491.7	10.7	391.5	328.5	709.3
1958	14.0	396.5	7.3	403.8	10.7	666.7	75.8	731.8
1959	3.9	546.5	9.2	555.7	10.8	246.7	510.9	746.8
1960	4.7	549.1	9.1	558.2	11.5	195.1	552.7	736.3
1961	5.5	555.5	9.1	564.6	11.5	132.0	608.6	729.1
1962	8.6	513.6	8.8	522.4	11.9	574.2	518.8	1081.1
1963	8.0	522.2	8.6	530.8	11.9	587.5	487.9	1063.5
1964	5.0	581.6	9.0	590.6	11.9	294.4	567.4	849.9
1965	7.6	559.3	9.0	568.3	11.9	615.9	496.6	1100.6
1966	5.7	606.5	9.5	616.0	11.9	431.9	551.1	971.1
1967	10.6	522.5	8.7	531.2	12.7	833.4	427.7	1248.4
1968	5.6	624.9	9.6	634.5	12.7	332.7	461.7	781.7
1969	15.6	510.0	8.9	518.9	13.1	820.2	394.6	1201.7
1970	5.6	646.1	10.0	656.1	13.1	552.2	432.8	971.9
1971	6.9	630.8	10.2	641.0	13.1	334.0	444.1	765.0
1972	3.6	688.2	11.2	699.4	13.8	243.0	479.2	708.4
1973	9.3	594.3	10.6	604.9	13.9	751.9	400.3	1138.3
1974	6.1	662.1	11.7	673.8	14.3	703.3	368.6	1057.6
1975	7.0	647.4	12.2	659.6	14.3	436.1	385.9	807.7
1976	6.9	628.7	12.3	641.0	15.0	70.1	464.1	519.2
1977	4.6	680.0	13.1	693.1	15.1	60.9	589.5	635.3
1978	15.8	516.1	12.1	528.2	15.5	785.9	173.3	943.7
1979	7.0	651.6	13.9	665.5	15.5	515.9	458.0	958.4
1980	8.4	623.1	14.1	637.2	16.2	626.4	370.4	980.6
AVG 22-80	7.7	393.0	7.2	400.2	9.1	391.1	281.8	663.9

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4R
WATER BUDGET FOR REGION 18 (DSA 60E)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	590.1	6.3	596.4	8.3	323.0	620.6	935.3
1923	8.0	635.0	6.6	641.6	8.3	232.8	761.8	986.3
1924	4.2	666.6	7.1	673.7	8.3	67.0	929.3	988.0
1925	7.9	640.8	7.0	647.8	8.4	307.9	710.4	1009.9
1926	6.6	662.4	7.1	669.5	8.4	181.2	831.5	1004.3
1927	9.7	613.6	6.9	620.5	9.1	455.1	588.9	1034.9
1928	6.8	672.6	7.1	679.7	9.5	149.2	882.7	1022.4
1929	6.4	682.2	7.7	689.9	9.5	172.4	863.5	1026.4
1930	5.9	664.6	7.8	672.4	9.5	161.4	847.1	999.0
1931	6.7	645.4	8.0	653.4	9.6	73.0	895.4	958.8
1932	9.2	594.8	8.2	603.0	10.3	456.1	548.6	994.4
1933	6.3	630.1	8.9	639.0	10.7	269.5	713.0	971.8
1934	3.1	664.9	9.4	674.3	10.7	96.1	916.7	1002.1
1935	12.5	507.2	8.3	515.5	11.5	334.0	508.4	830.9
1936	8.1	566.2	9.3	575.5	11.9	491.8	491.7	971.6
1937	11.5	504.9	9.1	514.0	11.9	632.2	408.6	1028.9
1938	13.1	465.8	9.3	475.1	12.7	667.3	362.0	1016.6
1939	7.3	542.5	10.4	552.9	13.1	235.9	628.0	850.8
1940	8.8	546.1	10.5	556.6	13.1	494.5	506.0	987.4
1941	13.9	501.2	10.5	511.7	13.9	586.7	419.5	992.3
1942	7.8	635.0	11.6	646.6	14.3	450.3	602.4	1038.4
1943	9.4	625.7	12.0	637.7	15.5	533.1	594.5	1112.1
1944	6.4	717.6	13.2	730.8	16.2	295.5	830.0	1109.3
1945	8.8	730.2	13.1	743.3	16.7	499.4	706.8	1189.5
1946	7.1	820.0	14.0	834.0	17.4	320.8	987.4	1290.8
1947	5.9	906.9	14.8	921.7	17.9	213.2	1205.1	1400.4
1948	5.5	916.4	15.2	931.6	19.0	210.4	1176.4	1367.8
1949	5.0	1007.4	16.2	1023.6	19.8	194.2	1328.0	1502.4
1950	6.0	1027.6	16.9	1044.5	20.3	468.0	1142.2	1589.9
1951	6.1	1056.4	17.2	1073.6	21.0	598.5	1118.0	1695.5
1952	10.4	945.0	16.4	961.4	21.4	1053.9	609.5	1642.0
1953	7.1	1069.4	17.8	1087.2	22.2	893.9	881.0	1752.7
1954	6.4	1098.8	18.0	1116.8	22.2	837.6	931.7	1747.1
1955	7.5	1135.4	18.3	1153.7	22.7	889.9	946.0	1813.2
1956	8.0	1190.1	18.8	1208.9	23.4	1259.6	778.1	2014.3
1957	5.7	1325.5	19.1	1344.6	23.8	974.9	1166.8	2117.9
1958	14.0	1082.4	16.4	1098.8	24.6	1204.2	669.1	1848.7
1959	3.9	1468.2	20.4	1488.6	24.6	740.3	1586.6	2302.3
1960	4.7	1449.5	20.5	1470.0	25.7	587.3	1652.8	2214.4
1961	5.5	1469.6	20.4	1490.0	25.8	353.6	1892.5	2220.3
1962	8.6	1345.9	19.7	1365.6	25.8	1240.3	1439.5	2654.0
1963	8.0	1343.4	19.4	1362.8	26.2	1369.2	1353.6	2696.6
1964	5.0	1482.9	20.1	1503.0	27.0	749.1	1574.3	2296.4
1965	7.6	1427.9	20.0	1447.9	27.0	1389.4	1377.5	2739.9
1966	5.7	1529.7	21.5	1551.2	27.4	842.5	1529.2	2344.3
1967	10.6	1316.4	19.4	1335.8	28.1	1581.1	1186.6	2739.6
1968	5.6	1540.6	21.5	1562.1	28.2	777.4	1281.1	2030.3
1969	15.6	1232.6	19.8	1252.4	28.2	1555.9	1093.5	2621.2
1970	5.6	1560.8	22.2	1583.0	29.3	1101.5	1200.7	2272.9
1971	6.9	1524.6	22.6	1547.2	29.4	874.3	1232.7	2077.6
1972	3.6	1646.7	25.1	1671.8	30.5	596.0	1329.2	1894.7
1973	9.3	1422.3	23.9	1446.2	30.6	1305.3	1111.0	2385.7
1974	6.1	1563.2	26.3	1589.5	31.7	1364.8	1022.8	2355.9
1975	7.0	1535.9	26.9	1562.8	32.2	1220.9	1070.5	2259.2
1976	6.9	1475.6	27.4	1503.0	32.9	466.9	1287.6	1721.6
1977	4.6	1582.0	29.4	1611.4	34.1	206.6	1636.0	1808.5
1978	15.8	1157.2	26.8	1184.0	34.1	1544.4	704.0	2214.3
1979	7.0	1499.6	31.1	1530.7	35.3	1412.6	1215.0	2592.3
1980	8.4	1425.0	31.2	1456.2	35.3	1616.7	877.0	2458.4
AVG 22-80	7.7	1021.8	16.1	1037.9	20.3	681.0	979.0	1639.7

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4S
WATER BUDGET FOR REGION 19 (DSA 60F)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	351.8	1.2	353.0	1.2	132.8	353.1	484.7
1923	8.0	379.8	1.2	381.0	1.2	69.9	381.0	449.7
1924	4.2	397.6	1.3	398.9	1.2	20.3	398.9	418.0
1925	7.9	382.3	1.3	383.6	1.2	65.9	383.7	448.4
1926	6.6	396.3	1.3	397.6	1.2	50.4	397.6	446.8
1927	9.7	366.8	1.3	368.1	1.2	113.5	368.2	480.5
1928	6.8	402.8	1.3	404.1	1.2	43.4	404.1	446.3
1929	6.4	406.8	1.4	408.2	1.2	47.2	408.3	454.3
1930	5.9	396.6	1.4	398.0	1.9	51.2	397.9	447.2
1931	6.7	384.7	1.5	386.2	2.3	21.5	386.3	405.5
1932	9.2	354.1	1.6	355.7	2.3	0.0	355.7	353.4
1933	6.3	375.1	1.6	376.7	2.4	71.4	376.7	445.7
1934	3.1	396.0	1.8	397.8	2.4	15.2	397.8	410.6
1935	12.5	303.8	1.7	305.5	2.4	102.6	305.6	405.8
1936	8.1	338.0	1.8	339.8	2.4	91.2	339.8	428.6
1937	11.5	302.2	1.6	303.8	2.4	104.2	303.9	405.7
1938	13.1	275.9	1.6	277.5	2.4	116.0	277.6	391.2
1939	7.3	323.6	1.8	325.4	2.4	81.7	325.5	404.8
1940	8.8	325.2	1.8	327.0	2.4	83.6	327.0	408.2
1941	13.9	297.2	1.8	299.0	2.4	118.1	299.1	414.8
1942	7.8	378.8	2.1	380.9	2.4	100.9	380.8	479.3
1943	9.4	373.8	2.2	376.0	2.4	104.0	376.0	477.6
1944	6.4	427.6	2.6	430.2	3.1	87.2	430.3	514.4
1945	8.8	436.2	2.4	438.6	3.5	104.6	438.7	539.8
1946	7.1	490.0	2.5	492.5	3.5	170.7	492.5	659.7
1947	5.9	541.6	2.7	544.3	3.6	65.5	544.2	606.1
1948	5.5	547.1	2.9	550.0	3.6	54.3	550.0	600.7
1949	5.0	600.6	3.1	603.7	3.6	43.1	603.6	643.1
1950	6.0	612.7	3.1	615.8	3.6	77.0	615.7	689.1
1951	6.1	629.6	3.2	632.8	3.6	65.7	632.9	695.0
1952	10.4	563.2	3.0	566.2	3.6	119.2	566.2	681.8
1953	7.1	637.3	3.3	640.6	3.6	91.0	640.5	727.9
1954	6.4	655.8	3.3	659.1	4.3	96.3	659.0	751.0
1955	7.5	664.0	3.4	667.4	4.3	47.8	667.4	710.9
1956	8.0	683.0	3.5	686.5	4.7	239.1	686.5	920.9
1957	5.7	750.5	3.6	754.1	4.7	78.9	754.1	828.3
1958	14.0	610.4	3.1	613.5	4.7	306.5	613.7	915.5
1959	3.9	822.4	3.7	826.1	4.8	67.1	826.2	888.5
1960	4.7	813.0	3.8	816.8	4.8	35.0	816.8	847.0
1961	5.5	827.2	3.7	830.9	4.8	0.0	830.8	826.0
1962	8.6	758.8	3.6	762.4	4.8	187.5	762.4	945.1
1963	8.0	764.7	3.5	768.2	4.8	134.8	768.3	898.3
1964	5.0	843.1	3.7	846.8	4.8	59.1	846.8	901.1
1965	7.6	815.6	3.7	819.3	4.8	135.1	819.3	949.6
1966	5.7	872.2	3.9	876.1	4.8	81.7	876.1	953.0
1967	10.6	759.0	3.6	762.6	4.8	281.0	762.6	1038.8
1968	5.6	883.3	4.1	887.4	4.8	89.8	887.3	972.3
1969	15.6	697.1	3.5	700.6	4.8	0.0	700.6	695.8
1970	5.6	898.6	4.2	902.8	5.5	235.0	902.9	1132.4
1971	6.9	880.3	4.2	884.5	5.9	216.0	884.5	1094.6
1972	3.6	953.9	4.8	958.7	5.9	171.5	958.7	1124.3
1973	9.3	830.1	4.4	834.5	5.9	313.4	834.6	1142.1
1974	6.1	914.3	4.9	919.2	6.0	470.9	919.2	1384.1
1975	7.0	907.4	5.1	912.5	6.0	489.3	912.4	1395.7
1976	6.9	878.5	5.1	883.6	6.0	334.3	883.7	1212.0
1977	4.6	940.4	5.3	945.7	6.0	245.8	945.7	1185.5
1978	15.8	680.3	5.1	685.4	6.0	411.2	685.5	1090.7
1979	7.0	899.7	5.7	905.4	6.7	538.6	905.3	1437.2
1980	8.4	859.3	5.7	865.0	6.7	599.5	865.1	1457.9
AVG 22-80	7.7	597.6	3.0	600.6	3.7	141.5	600.6	738.4

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4T
WATER BUDGET FOR REGION 20 (DSA 60G)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	138.0	2.2	140.2	2.4	95.2	180.4	273.2
1923	8.0	148.5	2.4	150.9	3.1	47.3	266.1	310.3
1924	4.2	157.9	2.5	160.4	3.1	13.3	330.9	341.1
1925	7.9	149.9	2.4	152.3	3.5	46.2	270.5	313.2
1926	6.6	155.1	2.5	157.6	3.5	33.7	298.2	328.4
1927	9.7	143.2	2.4	145.6	3.5	80.8	211.1	288.4
1928	6.8	158.0	2.6	160.6	3.6	31.4	307.8	335.6
1929	6.4	160.0	2.7	162.7	3.6	33.2	310.0	339.6
1930	5.9	157.0	2.9	159.9	3.6	37.4	298.3	332.1
1931	6.7	151.8	2.7	154.5	3.6	15.0	316.0	327.4
1932	9.2	138.5	2.8	141.3	3.6	133.1	148.5	278.0
1933	6.3	148.2	3.2	151.4	3.6	48.8	265.2	310.4
1934	3.1	156.4	3.5	159.9	3.6	0.0	347.1	343.5
1935	12.5	118.4	2.9	121.3	3.6	61.3	183.7	241.4
1936	8.1	132.7	3.4	136.1	4.3	137.7	147.7	281.1
1937	11.5	117.7	3.2	120.9	4.7	113.4	137.0	245.7
1938	13.1	108.5	3.3	111.8	4.7	197.2	97.6	290.1
1939	7.3	127.4	3.7	131.1	4.8	100.7	180.3	276.2
1940	8.8	128.1	3.8	131.9	4.8	116.2	158.5	269.9
1941	13.9	116.7	3.7	120.4	4.8	146.1	134.4	275.7
1942	7.8	148.5	4.1	152.6	4.8	87.5	217.6	300.3
1943	9.4	146.8	4.3	151.1	5.9	59.0	251.3	304.4
1944	6.4	169.0	4.7	173.7	5.9	114.5	228.1	336.7
1945	8.8	170.6	4.7	175.3	6.0	145.5	193.8	333.3
1946	7.1	192.3	5.1	197.4	6.0	117.4	279.4	390.8
1947	5.9	212.8	5.2	218.0	6.7	56.2	400.0	449.5
1948	5.5	217.0	5.4	222.4	7.1	47.4	421.2	461.5
1949	5.0	238.5	5.8	244.3	7.1	59.2	453.4	505.5
1950	6.0	241.8	6.1	247.9	7.2	79.2	435.2	507.2
1951	6.1	247.3	6.0	253.3	7.2	94.5	427.2	514.5
1952	10.4	220.0	5.9	225.9	7.2	246.7	176.0	415.5
1953	7.1	250.4	6.3	256.7	7.9	216.0	277.9	486.0
1954	6.4	258.8	6.5	265.3	8.3	217.0	296.0	504.7
1955	7.5	263.8	6.4	270.2	8.3	150.5	394.9	537.1
1956	8.0	273.0	6.6	279.6	8.3	317.5	215.5	524.7
1957	5.7	303.4	6.9	310.3	8.4	203.3	424.7	619.6
1958	14.0	245.9	5.9	251.8	8.4	333.4	145.1	470.1
1959	3.9	339.6	7.4	347.0	9.1	218.6	483.7	693.2
1960	4.7	340.6	7.5	348.1	9.1	209.8	492.3	693.0
1961	5.5	347.0	7.2	354.2	9.5	152.4	576.9	719.8
1962	8.6	320.8	7.0	327.8	9.5	307.0	489.6	787.1
1963	8.0	328.3	7.0	335.3	9.5	323.3	460.2	774.0
1964	5.0	367.0	7.2	374.2	9.5	259.3	535.3	785.1
1965	7.6	354.3	7.1	361.4	9.5	319.6	468.5	778.6
1966	5.7	383.5	7.7	391.2	9.6	264.3	520.1	774.8
1967	10.6	333.1	7.0	340.1	9.6	448.1	403.9	842.4
1968	5.6	396.5	7.7	404.2	10.3	251.3	435.7	676.7
1969	15.6	317.7	7.1	324.8	10.3	422.2	371.9	783.8
1970	5.6	411.0	8.0	419.0	10.7	348.6	408.3	746.2
1971	6.9	403.0	7.9	410.9	10.7	259.7	419.1	668.1
1972	3.6	442.4	9.0	451.4	10.7	242.0	452.1	683.4
1973	9.3	386.2	8.5	394.7	10.8	370.1	378.1	737.4
1974	6.1	434.8	9.3	444.1	11.5	368.5	347.8	704.8
1975	7.0	432.8	9.7	442.5	11.9	351.2	363.9	703.2
1976	6.9	426.4	9.8	436.2	11.9	189.1	438.0	615.2
1977	4.6	468.1	10.4	478.5	11.9	105.9	556.5	650.5
1978	15.8	341.1	9.8	350.9	11.9	402.1	301.7	691.9
1979	7.0	453.7	10.9	464.6	12.7	354.0	561.1	902.4
1980	8.4	437.1	11.1	448.2	13.1	525.6	327.5	840.0
AVG 22-80	7.7	255.5	5.7	261.3	7.3	181.8	332.5	507.0

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.4U
WATER BUDGET FOR REGION 21 (DSA 60H)

YEAR	RAIN (in) (1)	CUAW IRR (TAF) (2)	CUAW URBAN (TAF) (3)	CUAW IRR+URB (TAF) (4)=(2)+(3)	DOMESTIC (INDOOR) (TAF) (5)	SW SUPPLY (TAF) (6)	ESTIMATED GW PMPNG (TAF) (7)	IRRIG SUPPLY (TAF) (8)=(6)+(7)
1922	9.9	339.9	6.1	346.0	7.9	443.7	213.0	648.8
1923	8.0	366.0	6.5	372.5	8.3	258.3	413.5	663.5
1924	4.2	384.9	6.9	391.8	8.3	82.8	628.8	703.3
1925	7.9	369.5	6.8	376.3	8.3	241.2	425.8	658.7
1926	6.6	381.1	7.1	388.2	8.4	173.6	530.4	695.6
1927	9.7	353.5	6.8	360.3	8.4	391.1	279.4	662.1
1928	6.8	389.2	6.9	396.1	9.1	153.4	561.5	705.8
1929	6.4	393.4	7.4	400.8	9.5	168.9	550.5	709.9
1930	5.9	384.4	7.6	392.0	9.5	181.2	520.7	692.4
1931	6.7	372.2	7.9	380.1	9.5	85.3	604.3	680.1
1932	9.2	342.0	8.0	350.0	10.3	170.9	455.0	615.6
1933	6.3	363.7	8.7	372.4	10.7	209.5	453.5	652.3
1934	3.1	382.0	9.3	391.3	10.7	122.7	583.9	695.9
1935	12.5	293.2	8.2	301.4	10.8	204.8	333.5	527.5
1936	8.1	326.7	9.1	335.8	11.5	259.1	336.2	583.8
1937	11.5	291.9	8.8	300.7	11.9	218.5	338.5	545.1
1938	13.1	267.8	9.0	276.8	11.9	213.9	305.1	507.1
1939	7.3	313.5	10.1	323.6	12.7	171.7	405.6	564.6
1940	8.8	314.7	10.2	324.9	13.1	207.3	375.2	569.4
1941	13.9	288.4	10.2	298.6	13.8	198.0	338.8	523.0
1942	7.8	366.0	11.3	377.3	14.3	196.0	477.5	659.2
1943	9.4	361.1	11.7	372.8	15.1	193.0	472.6	650.5
1944	6.4	414.2	13.1	427.3	15.5	203.8	560.8	749.1
1945	8.8	420.8	12.8	433.6	16.3	244.7	527.3	755.7
1946	7.1	473.3	13.9	487.2	17.4	194.9	680.6	858.1
1947	5.9	523.5	14.6	538.1	17.9	168.5	803.2	953.8
1948	5.5	528.7	14.7	543.4	18.6	146.8	836.7	964.9
1949	5.0	581.9	16.0	597.9	19.1	126.5	959.3	1066.7
1950	6.0	593.8	16.7	610.5	19.8	164.9	940.1	1085.2
1951	6.1	608.2	16.7	624.9	20.3	156.1	976.1	1111.9
1952	10.4	543.3	16.2	559.5	21.0	276.6	723.7	979.3
1953	7.1	616.1	17.4	633.5	21.4	144.9	1004.3	1127.8
1954	6.4	635.4	17.5	652.9	22.2	146.4	1038.4	1162.6
1955	7.5	646.2	17.9	664.1	22.2	131.3	1075.5	1184.6
1956	8.0	667.5	18.4	685.9	22.7	227.1	1010.1	1214.5
1957	5.7	734.3	18.7	753.0	23.4	146.2	1222.3	1345.1
1958	14.0	599.1	16.0	615.1	23.8	317.2	781.0	1074.4
1959	3.9	808.2	20.1	828.3	24.6	136.5	1371.5	1483.4
1960	4.7	798.6	20.1	818.7	24.6	124.6	1366.8	1466.8
1961	5.5	809.6	19.8	829.4	25.0	90.9	1423.6	1489.5
1962	8.6	739.9	19.2	759.1	25.8	137.3	1315.4	1426.9
1963	8.0	743.9	19.1	763.0	25.8	208.0	1237.0	1419.2
1964	5.0	818.0	19.8	837.8	26.2	136.0	1438.3	1548.1
1965	7.6	789.3	19.5	808.8	26.9	175.4	1258.7	1407.2
1966	5.7	845.4	21.0	866.4	27.0	166.8	1397.3	1537.1
1967	10.6	726.3	19.0	745.3	27.0	374.3	1084.3	1431.6
1968	5.6	851.9	21.0	872.9	27.4	249.2	1170.6	1392.4
1969	15.6	677.1	19.5	696.6	28.1	516.7	999.0	1487.6
1970	5.6	865.7	21.6	887.3	28.2	350.5	1097.0	1419.3
1971	6.9	839.7	22.0	861.7	29.3	340.6	1126.3	1437.6
1972	3.6	907.4	24.5	931.9	29.4	308.9	1214.6	1494.1
1973	9.3	791.1	23.2	814.3	30.5	529.0	1015.1	1513.6
1974	6.1	880.0	25.8	905.8	30.6	578.6	934.7	1482.7
1975	7.0	872.9	26.3	899.2	31.7	485.5	978.1	1431.9
1976	6.9	845.1	26.7	871.8	32.2	496.9	1176.6	1641.3
1977	4.6	902.7	28.8	931.5	32.9	228.3	1494.7	1690.1
1978	15.8	671.1	26.3	697.4	34.1	486.5	791.2	1243.6
1979	7.0	871.6	30.4	902.0	34.1	793.8	898.6	1658.3
1980	8.4	836.2	30.5	866.7	35.3	953.1	763.1	1680.9
AVG 22-80	7.7	578.4	15.8	594.1	19.9	257.8	818.6	1056.5

SOURCES OF DATA---
RAIN: CONSUMPTIVE USE MODEL (DWR)
CUAW: CONSUMPTIVE USE MODEL (DWR)
DOMESTIC USE: CONSUMPTIVE USE MODEL (DWR)
SW SUPPLY: USBR, DWR/DEPLETION MODEL, USGS, DISTRICTS
GW PUMPING: USBR POWER RECORDS, PREVIOUS MODELS

TABLE 3.5A

SURFACE WATER DIVERSIONS

SYSTEM	PERIOD OF RECORD HISTORIC DATA	PERIOD OF RECORD ESTIMATED DATA	SOURCE OF HISTORIC DATA*
Whiskeytown Conduit (Clear Creek South Unit)	67-80	---	USBR[4]
Bella Vista Conduit (Cow Creek Unit)	67-80	---	USBR[4]
Sacramento River			
Red Bluff to Redding	22-77	78-80	JHS; DWR[1]; USBR[4]
Redding to NCP	22-77	78-80	JHS; DWR[1]; USBR[4]
NCP to Delta	22-77	78-80	JHS; DWR[1]; USBR[4]
Stony Creek			
North Canal	52-80	22-51	USBR[4]
South Canal	52-80	22-51	USBR[4]
Corning Canal	61-80	---	USBR[4]
Tehama - Colusa Canal (irrigation only)	75-80	---	USBR[4]
Glenn-Colusa Canal	22-80	---	DWR[2]
Feather River	24-80	22-23	DWR[1]; DWR[3]; DWR[5]
Yuba River	26-80	22-25	DWR[1]; DWR[5]
Tarr Ditch	22-80	---	DWR[2]
Miocene and Wilenor Canals (irrigation only)	22-80	---	DWR[5]
Palermo Canal	22-80	---	DWR[2]
Forbestown Ditch	22-80	---	DWR[2]
Miners Ranch Canal (irrigation only)	63-80	---	DWR[2]
Boardman Canal	22-80	---	DWR[2]
Combie (Gold Hill) Canal	22-80	---	DWR[2]
South Canal	22-80	---	DWR[2]
Colusa Basin Drain (irrigation only)	24-65	22-23, 66-80	(see discussion)
Knights Landing Ridge Cut Analysis	22-80	---	DWR[2]

* for footnotes, please see last table of sequence 3.5 (3.5C)

TABLE 3.5B

SURFACE WATER DIVERSIONS

SYSTEM	PERIOD OF RECORD HISTORIC DATA	ESTIMATED DATA	SOURCE OF HISTORIC DATA*
Cache Creek	27-80	22-26	(see discussion)
Capay ID			
Bear River			
Camp Far West ID	22-80	---	DWR[1]
Bear River Canal	22-80	---	DWR[2]
American River			
North Fork Natomas	22-80	---	DWR[3]; USBR[4]
Carmichael WD	22-80	---	DWR[3]; USBR[4]
City of Sacramento			
American River	22-80	---	City of Sacramento
Sacramento River	64-80	---	City of Sacramento
Contra Costa Canal	41-80	---	USBR[4]
Putah South Canal	60-80	---	USBR[4]
Folsom South Canal	73-80	---	USBR[4]
Cosumnes River	49-70	22-48,71-80	DWR[1]
Mokelumne River	49-75	22-48,76-80	DWR[1]
Calaveras River	49-62	22-48,63-80	DWR[1]
San Joaquin River			
Vernalis to Fremont Ford	49-70	22-48, 71-80	DWR[1]
Fremont Ford to Gravelly Ford	41-80	22-40	DWR[3]; DWR-San Joaquin Div
Gravelly Ford to Friant Dam	49-70	22-48, 71-80	DWR[1]
Stanislaus River			
Riparians	28-70	22-27, 71-80	DWR[1]
South San Joaquin Canal	22-80	---	USGS
Oakdale Canal	22-80	---	USGS
Tuolumne River			
Riparians	28-70	22-27, 71-80	DWR[1]
Modesto Canal	22-80	---	USGS
Turlock Canal	22-80	---	USGS
Merced River			
Riparians	28-70	22-27, 71-80	DWR[1]
Merced ID North Canal	55-80	22-54	Merced ID
Merced ID Main Canal	55-80	22-54	Merced ID
Chowchilla River		22-80	(see discussion)
Fresno River		22-80	(see discussion)

* for footnotes, please see last table of sequence 3.5 (3.5C)

TABLE 3.5C

SURFACE WATER DIVERSIONS

SYSTEM	PERIOD OF RECORD HISTORIC DATA	ESTIMATED DATA	SOURCE OF HISTORIC DATA*
Delta Mendota Canal			
Tracy Pumping	51-80	---	USBR[4]
O'Neil Pumping	67-80	---	DWR[3]
O'Neil Generation	67-80	---	DWR[3]
Canal Diversions	51-80	---	USBR[4]
Deliveries to Mendota Pool	51-80	---	DWR[3]
Export to DSA 49A	51-80	---	USBR[4]
O'Neill Forebay			
San Luis Water District	68-80	---	DWR[3]
San Luis Canal			
San Luis Water District	68-80	---	DWR[3]
Panoche Water District	68-80	---	DWR[3]
Westlands Water District	68-80	---	DWR[3]
Diversions from Mendota Pool			
DSA 49A	22-80	---	DWR[1]; USBR[4]
DSA 49D	22-80	---	DWR[1]; USBR[4]
DSA 60A	64-80	---	USBR[4]
DSA 60B	22-80	---	DWR[1]; USBR[4]
Madera Canal	44-80	---	USBR[4]
Friant-Kern Canal	49-80	----	USBR[4]
Kings River	22-78	79-80	Kings River Water Association
Kaweah River	22-80	---	DWR Bulletin 49
Tule River	50-80	22-49	Tule River Association
Kern River	33-78	22-32,79-80	Kern River Watermaster Reports
California Aqueduct	70-80	---	DWR[3]
Cross Valley Canal	76-80	---	USBR[4]

JHS - 1957 Joint Hydrology Study
1 - DWR Bulletin 23 and 130
2 - DWR Depletion Analysis data
3 - DWR Reports of Operation
4 - USBR Reports of Operation
5 - DWR unpublished records (DWR, 1990b)

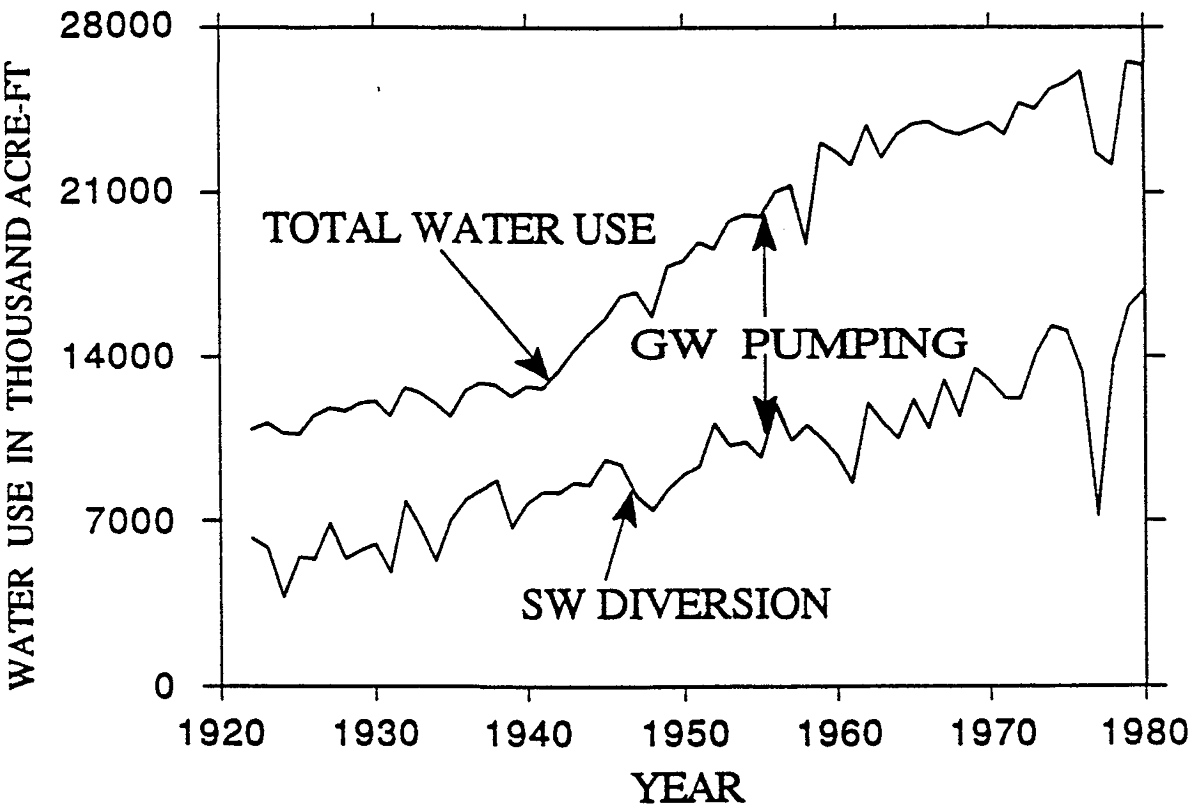

FIGURE 3.9

CENTRAL VALLEY HISTORIC WATER USE

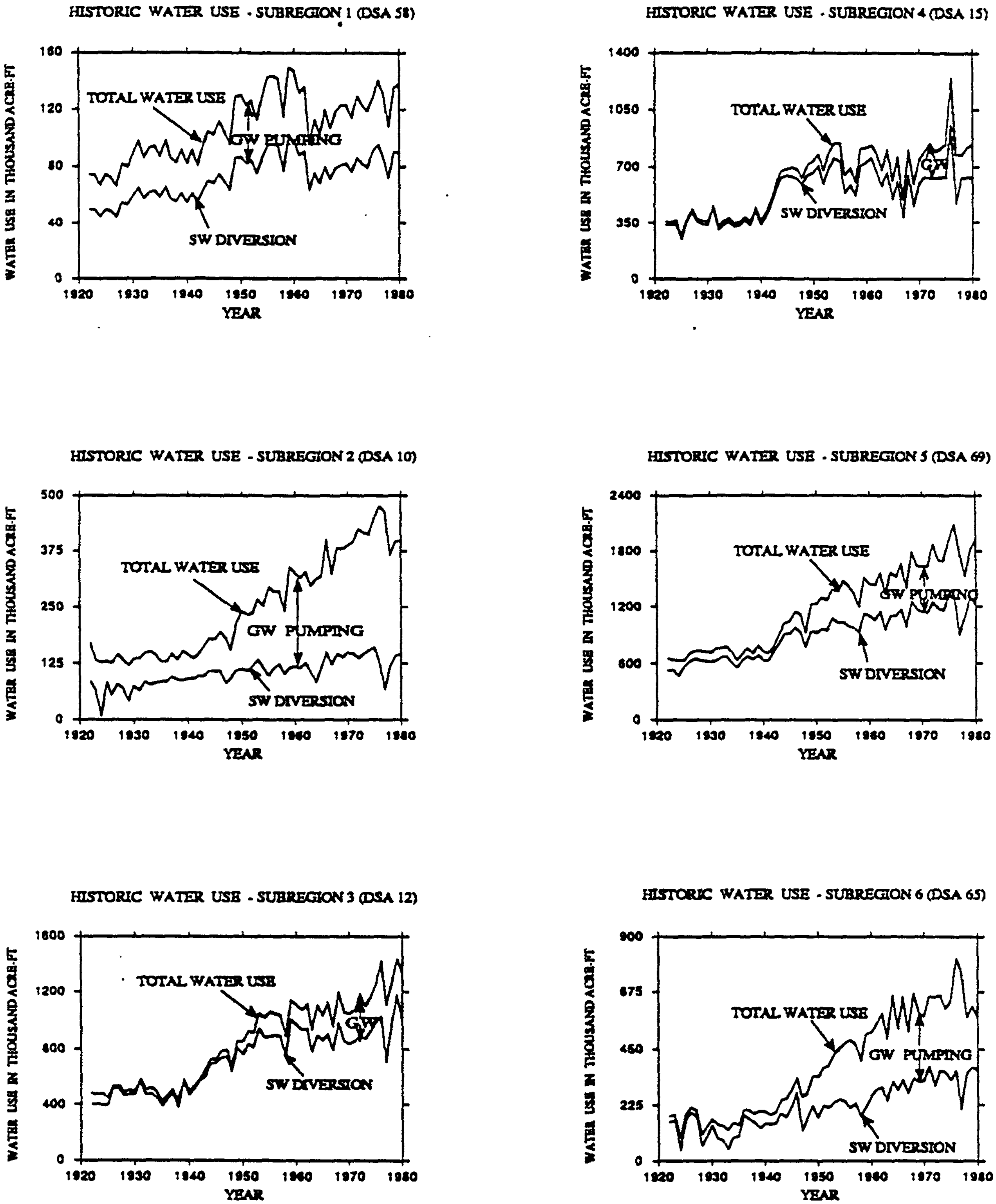

FIGURE 3.10(a)

SUBREGIONAL WATER USE

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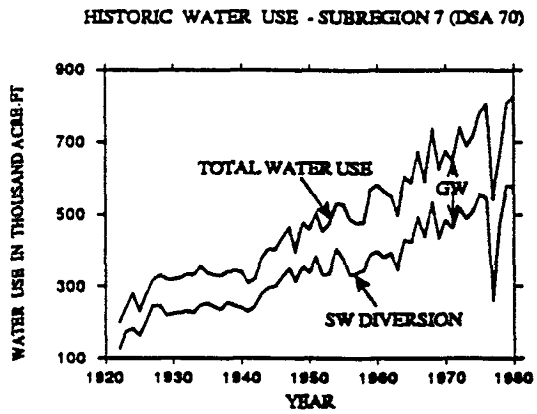
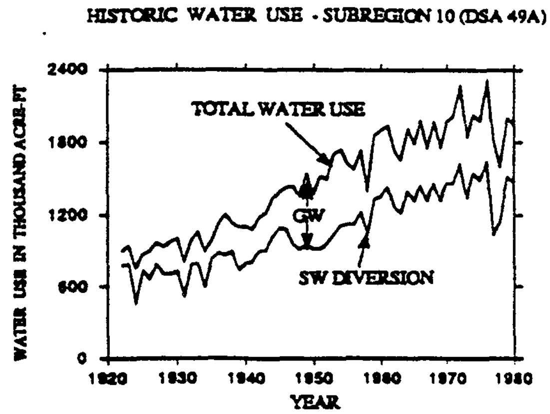
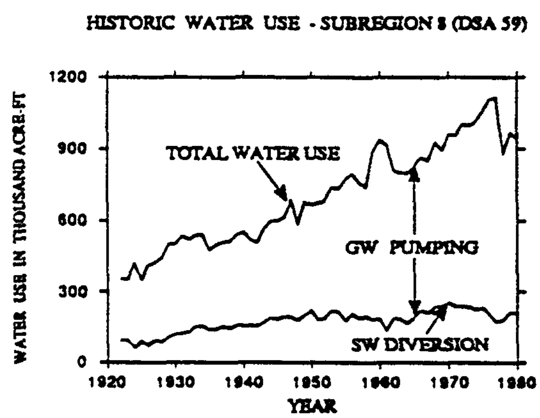
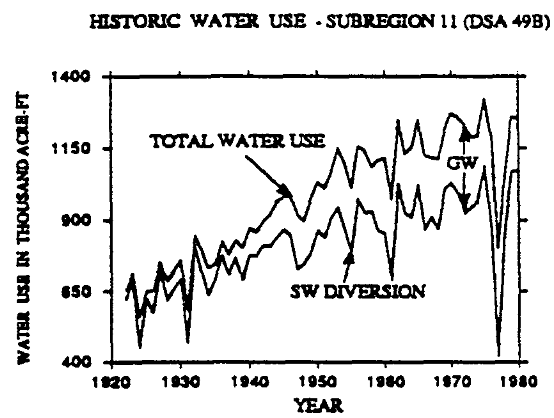
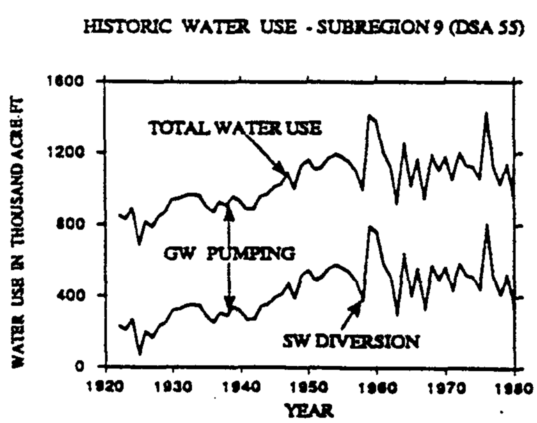










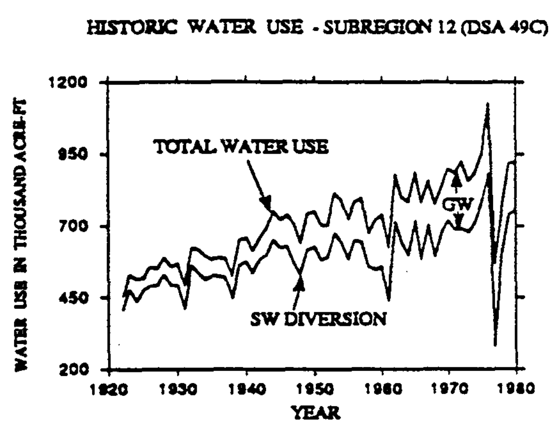


FIGURE 3.10(b)

SUBREGIONAL WATER USE

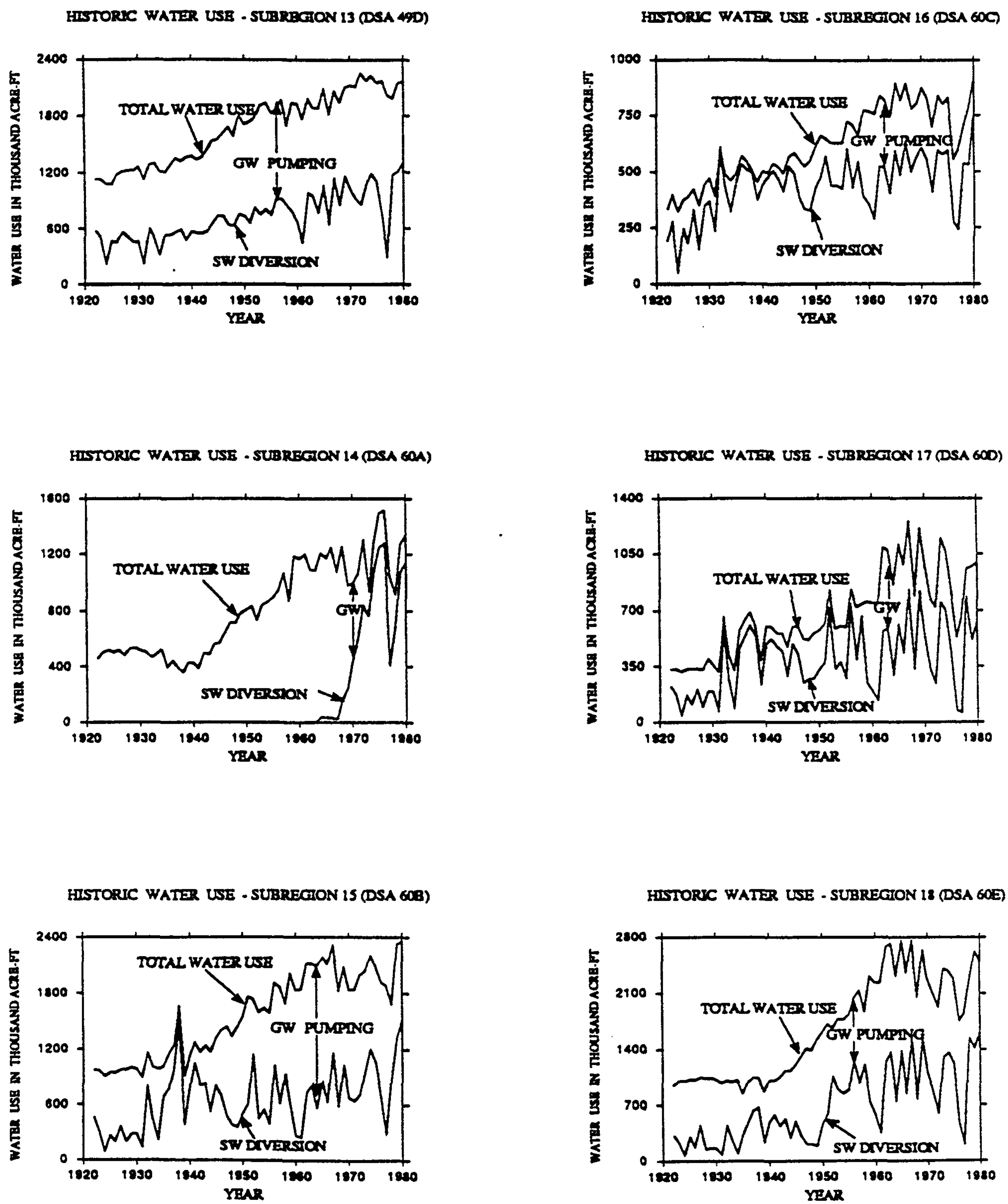
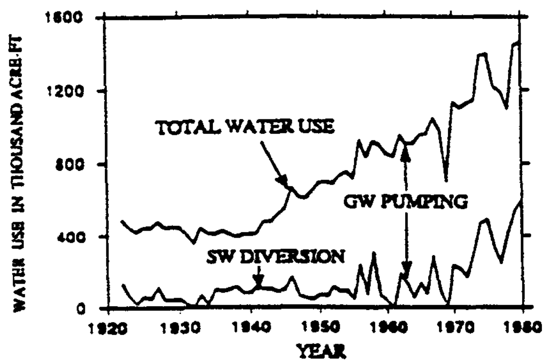


FIGURE 3.10(c)

SUBREGIONAL WATER USE

HISTORIC WATER USE - SUBREGION 19 (DSA 60F)



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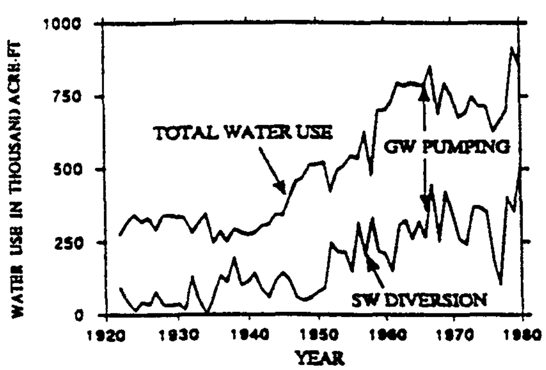

HISTORIC WATER USE - SUBREGION 21 (DSA 60H)

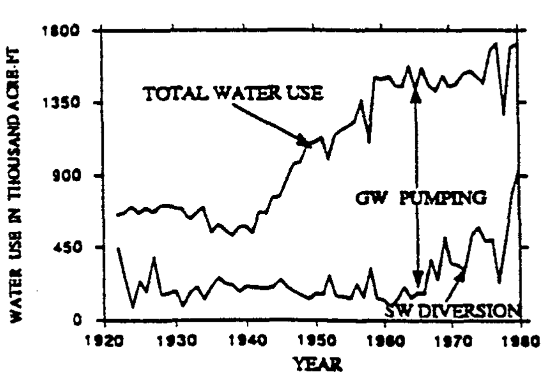

FIGURE 3.10(d)

SUBREGIONAL WATER USE

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provided by the National Oceanic and Atmospheric Administration (NOAA). More detailed discussion is provided in the hydrology section of this report.

- The consumptive use of applied water from agricultural and urban areas was obtained from the DWR's Consumptive Use (CU) model. Consumptive use of a crop is the amount of water required to satisfy the evapotranspirative demand of the crop including evaporation loss from crop foliage and adjacent soils. The portion of the consumptive use that is met by irrigation water is called the consumptive use of applied water. Using precipitation, crop acreage, and evapotranspiration data, the CU model determines the historic consumptive use of applied water of agricultural and urban vegetation by soil moisture accounting. It should be noted that for the subregions of DSA 49 and DSA 60, crop acreages were developed using subregional crop distribution factors obtained by analyzing DWR's 1980 Land Use Survey data, as discussed in the Land Use section of this report. The consumptive use of applied water was then calculated for each subregion using the CU model. Due to the lack of data, it was assumed that the crop acreage distribution pattern in those subregions remain unchanged for the duration of the study period.

- The domestic indoor water use is estimated so as to separate this non-consumptive type use from the total irrigation supply. The CU model uses an indoor use factor of 140 gallons per capita per day and historic population data from U.S. Census reports to estimate domestic indoor use. For the San Joaquin Basin above Vernalis (DSA 49A through 49D) and for Tulare Basin (DSA 60A through 60H), the subregional population was calculated by using a factor derived from an assessment of subregional and total urban acreage data from 1980 Land Use survey data. As mentioned earlier, the domestic indoor use is relatively small, hence any error in the estimates will not significantly affect the outcome of the water budget analysis.

A key objective of the water budget analysis was to develop a tool for estimating and validating the total irrigation supply. It provided a reliable check for assessing the accuracy of the total surface water diversion data on a subregional basis. The water budget analysis also provided the foundation from which the groundwater pumping estimates were derived. Due to the complexities associated with the surface water diversion data compilation and validation, and with the estimation of groundwater pumping, a separate section has been devoted to each water use component as presented below.

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Historic Surface Water Diversions:

The major surface water systems supplying water to the Central Valley include: the Federal Central Valley Project, the State Water Project, as well as large private conveyance systems. An intensive effort was made to collect data for all major surface water diversions utilized in the study area. The data was assembled according to surface water use by subregion. Table 3.5 a-c provides a list of all the surface water diversions collected for this study including diversion source, period of historic data, period of estimated data, and source of historic data. Figure 3.11a-b shows the specific surface water diversion points, corresponding to their physical locations. Table 3.6 a-d provides a matrix on a model subregional basis showing the interrelationship between the different subregions with respect to surface water inflows, outflows, diversions, imports, and exports.

The INFLOW column includes all perennial streams entering into a given subregion. The subregion in parenthesis for a given inflow indicates the upstream subregion; if no subregion is shown, then the inflow is from outside the model boundary. The OUTFLOW column shows streams flowing out of a particular subregion. The subregion in parenthesis, in this case, signifies the direction of the outflow. The DIVERSION column lists all diversions made within the subregion. This includes water used within the subregion, and exported to adjacent subregions (indicated in parenthesis). The importation of surface water from outside the model area or adjacent subregions (indicated in parenthesis) is listed in the IMPORT column. And the last column, EXPORT, indicates all water diverted in a subregion that is exported for use in adjacent subregions (this subregion is shown in parenthesis). Tables 3.6 a-d is a testimonial of the effort contributed to the development of a comprehensive accounting of the streamflow and surface water diversion interaction for the entire Central Valley. To date, no such example of all-inclusive surface water relationships is known to have been developed for the Central Valley of California. Very little historic diversion data was available in a digitized format prior to the initiation of this study. Digitized data consisted of Yuba, Bear, and American River foothill basin imports to DSAs 69 and 70 and a few isolated diversions as measured by USGS were available in digitized format through HYDRODATA. All other data was digitized from various sources, primarily: the 1957 Joint Hydrology Study, DWR Bulletins 23 and 130, USBR Reports of Operations, Watermaster Reports, and water district files. The 1957 Joint Hydrology Study report was prepared by USBR and DWR in support of the hydrology used by each agency in early planning studies. The primary focus of this report was the Sacramento River basin data for the period 1922-1954. None of the data contained therein was digitized prior to this study. During this study, a substantial portion of the data was digitized.

DWR Bulletins 23 and 130, also referred to as the Water Supervisor's Reports, were prepared annually by DWR. Bulletin 23 was initially published in 1928 that included data for years 1924 through 1928. Starting in 1929, DWR began

TABLE 3.6A
STREAMS AND DIVERSIONS BY SUBREGION

DSA	INFLOW	OUTFLOW	DIVERSION	IMPORT	EXPORT
58	Sacramento R. Cottonwood Ck. Cow Ck. Battle Ck. Paynes Ck.	Sacramento R. (DSA 10)	Bella Vista Conduit Sacramento R. Kes.-Red Bluff	Wiskeytown Conduit	Sacramento R. Kes.-Red Bluff(out of model bound.)
10	Sacramento R. (DSA 58) Elder Ck. Thomes Ck. Stony Ck. Antelope Ck. Mill Ck. Deer Ck. Big Chico Ck.	Sacramento R. (DSA 15)	Corning Cn. Stony Ck. (N. & S. Canals) Tehama-Colusa Cn. (DSA 12) Glenn-Colusa Cn. (DSA 12)	- - - -	Tehama-Colusa Cn. (DSA 12) Glenn-Colusa Cn. (DSA 12)
12	- - - -	- - - -	Knights Lnd. Rid. (DSA 65)	Tehama-Colusa Cn. (DSA 10) Glenn-Colusa Cn. (DSA 10)	Knights Lnd. Rid. for Irrig. (DSA 65) Colusa Basin Drain flood flows to Yolo Bypass (DSA 65)*
15	Sacramento R. (DSA 10)	Sacramento R. (DSA 70)	Sacramento R. Red Bluff-Knights Lnd.	Sacramento R. Red Bluff-Knights Lnd. (DSA 15)	Sacramento R. Red Bluff-Knights Lnd. (DSA 12) Tisdale Weir-Sutter Bypass (DSA 69)*
69	Feather R. Butte Ck. Yuba R. Bear R.	Feather R. (DSA 70)	Feather R. Feather R. (DSA 70) Yuba R. Bear R. (DSA 70)	Tarr Ditch (55%) Bear R. Camp Far West ID Miocene and Wilenor Cn. Palermo Cn. Forbestown Ditch Miners Ranch Cn. (Irr. only) Tisdale Weir*	Feather R. (DSA 70) Bear R. (DSA 70)

* These flows treated as bypasses.

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TABLE 3.6B
STREAMS AND DIVERSIONS BY SUBREGION

DSA	INFLOW	OUTFLOW	DIVERSION	IMPORT	EXPORT
65	Cache Ck. Putah Ck.	- - - -	Cache Ck. Putah South Cn.	Sacramento R. Right Bk. Knts Lnd-Sac (DSA 55) Knights Lnd Rid. (DSA 12) Colusa Basin Drn flood flow to Yolo Byp (DSA 12)* Fremont Weir-Yolo Byp (DSA 70)* Sacramento Weir-Yolo Byp (DSA 55)*	Putah South Cn. to North Bay Yolo Byp to Sac R (DSA 55)*
70	Sacramento R. (DSA 15) American R.	Sacramento R. (DSA 55)	American R. Carmichael ID American R.-Sac (DSA 59) Folsom South Cn. (DSA 59)	Feather R. (DSA 69) Bear R. (DSA 69) Sacramento R. Left Bank Knights Lnd.-Sac. (DSA 55) Boardman Cn. (75%) Bear R. Cn. Combie (Gold Hill) Cn. American R. N. Fork, Natomas Ditch, Folsom Pmp.	American R.-Sac. (DSA 59) Folsom South Cn. (DSA 59) Fremont Weir-Yolo Byp (DSA 65)*
59	Cosumnes R. Dry Ck. Mokelumne R. Calaveras R.	Cosumnes R. (DSA 55) Dry Ck. (DSA 55) Mokelumne R. (DSA 55) Calaveras R. (DSA 55)	Cosmunes R. Mokelumne R. Calaveras R.	Sacramento R.-Sac. (DSA 55) Folsom South Cn. (DSA 70) American R Sac. City (DSA 70)	Sacramento R. Knts Lnd.-Sac. (DSA 70) Sacramento R. Rt. Bank Knts Lnd-Sac. (DSA 65) Sacramento R.-Sac. (DSA 59)
55	Sacramento R. (DSA 70) Cosumnes R. (DSA 59) Dry Ck. (DSA 59) Mokelumne R. (DSA 59) San Joaquin R (DSA 49A)	Delta Outflow	San Joaquin R. Delta Lowlands	Yolo Bypass-Sac R. (DSA 65)*	- - - -

* These flows treated as bypasses.

TABLE 3.6C
STREAMS AND DIVERSIONS BY SUBREGION

DSA	INFLOW	OUTFLOW	DIVERSION	IMPORT	EXPORT
49A	Orestimba Ck Stanislaus R. Tuolumne R. Merced R. Bear Ck. Deadman's Ck. Chowchilla R. Fresno R. San Joaquin R.	San Joaquin R. (DSA 55)	San Joaquin R. from Fremont Ford-Vernalis	Delta Mendota Cn. Mendota Pool O'Neill Forebay San Luis Cn. Fresno Slough (DSA 60B)*	- - - -
49B	Stanislaus R. Tuolumne R.	Stanislaus R. (DSA 49A) Toulumne R. (DSA 49A)	South San Joaquin Cn. Oakdale Cn. Stanislaus R. Modesto Cn. Tuolumne R. Right Bk. Tuolumne R. Lt Bk. (DSA 49C) Turlock Cn. (DSA 49C)	- - - -	Tuolumne R. left Bk. (DSA 49B) Turlock Cn. (DSA 49B)
49C	Merced R.	Merced R. (DSA 49A)	Merced I.D. Northside Cn. Merced I.D. Main Cn. (DSA 49D) Merced R. Right Bk. Merced R. Left Bk. (DSA 49D)	Tuolumne R. Left Bk. (DSA 49B) Turlock Cn. (DSA 49B)	Merced ID Main Cn. (DSA 49C) Merced R. left Bk. (DSA 49C)
49D	Bear Ck. Deadman's Ck. Chowchilla R. Fresno R. San Joaquin R.	Bear Ck (DSA 49A) Deadman's Cr. (DSA 49A) Chowchilla R. (DSA 49A) Fresno R. (DSA 49A) San Joaq R (DSA 49A)	Chowchilla R. Fresno R. San Joaq. R. Right Bk. San Joaq. R. Left Bk. (DSA 60C)	Mendota Pool Merced R. Left Bk. (DSA 49C) Merced I.D. Main Cn. (DSA 49C) Madera Cn.	San Joaquin R. (DSA 49D)

* These flows treated as bypasses.

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TABLE 3.6D
STREAMS AND DIVERSIONS BY SUBREGION

DSA	INFLOW	OUTFLOW	DIVERSION	IMPORT	EXPORT
60A	- - - -	- - - -	- - - -	Mendota Pool San Luis Cn.	- - - -
60B	Kings R. (DSA 60D) Kaweah R. (DSA 60E) Tule R. (DSA 60E)	- - - -	- - - -	Mendota Pool Friant-Kern Cn. Kings R. (DSA 60D) Kaweah R. (DSA 60E) California Aq.	Fresno Slough (DSA 49A)*
60C	- - - -	- - - -	- - - -	San Joaquin R. Left Bk. (DSA 49D) Friant-Kern Cn. Kings R. (DSA 60D)	- - - -
60D	Kings R.	Kings R. (DSA 60B)	Kings R. Kings R. (DSA 60B) Kings R. (DSA 60C)	Friant-Kern Cn.	Kings R. (DSA 60B) Kings R. (DSA 60C)
60E	Kaweah R. Tule R.	Tule R. (DSA 60B)	Kaweah R. Kaweah R. (DSA 60B) Tule R.	Friant-Kern Cn.	Kaweah R. (DSA 60B)
60F	- - - -	- - - -	- - - -	Friant-Kern Cn. California Aq. Kern R. (DSA 60H)	Cross Valley Cn. (DSA 60H)
60G	- - - -	- - - -	- - - -	Friant-Kern Cn. Kern R. (DSA 60H)	- - - -
60H	Kern R.	- - - -	Kern R. Kern R. (DSA 60F) Kern R. (DSA 60G)	Friant-Kern Cn. California Aq. Cross Valley Cn. (DSA 60F)	Kern R. (DSA 60F) Kern R. (DSA 60G)

* These flows treated as bypasses.

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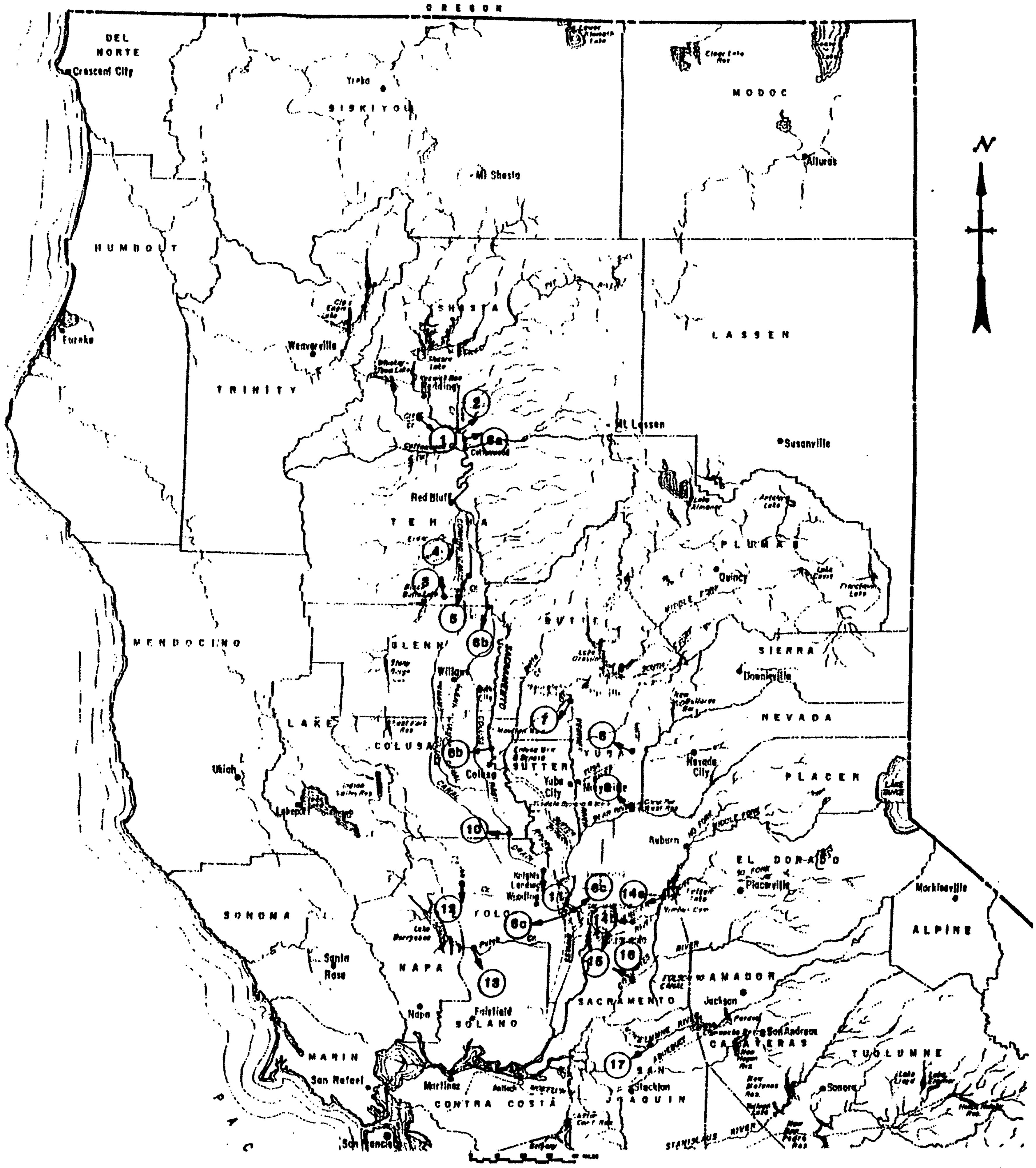
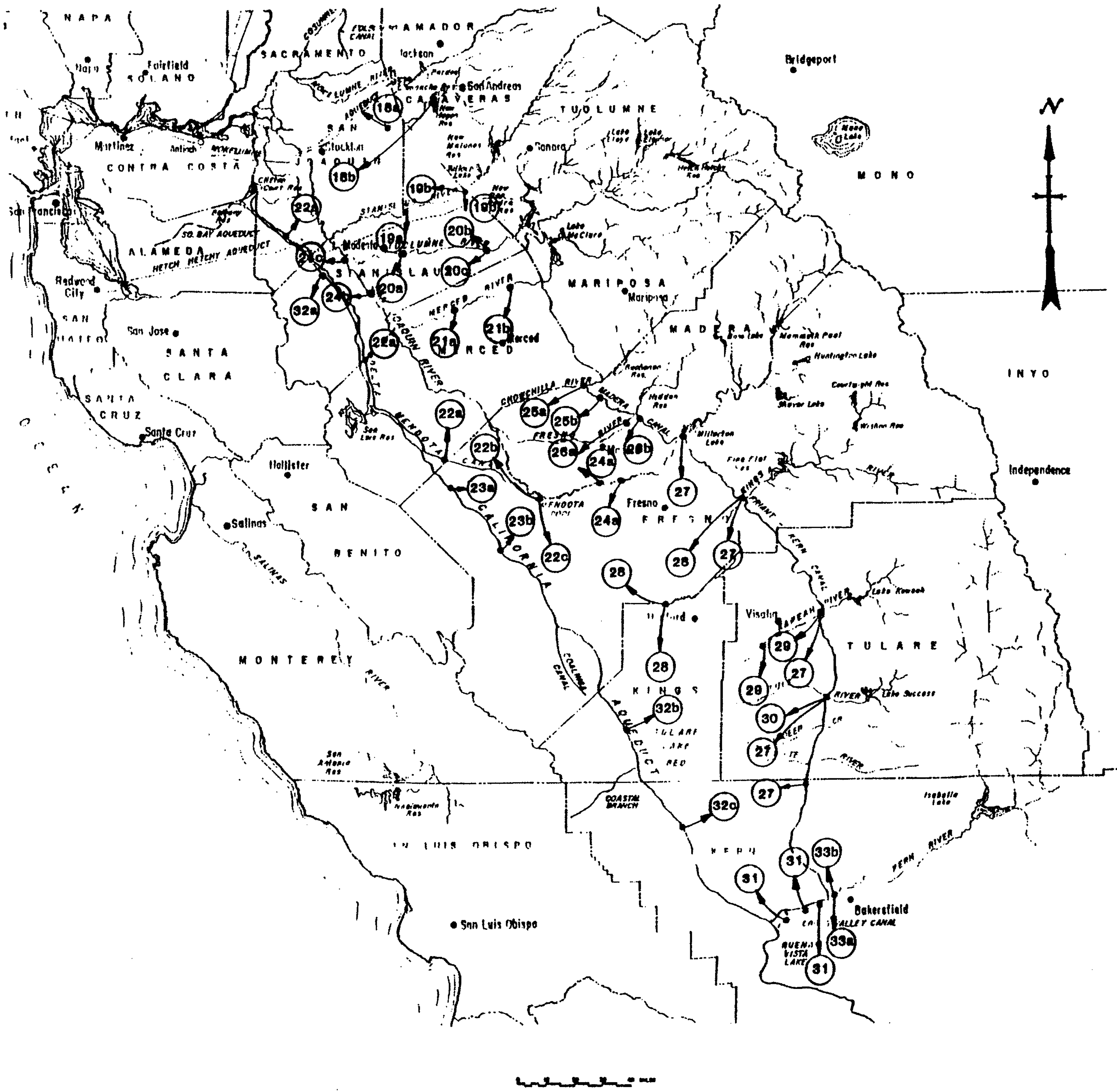


DIVERSION POINTS

1. Clear Creek Unit
2. Cow Creek Unit
3. Stony Creek Water Users
4. Corning Canal
5. Tehama Colusa Canal
6. Sacramento River Diverters
   - a. Keswick to Red Bluff
   - b. Red Bluff to Knights Landing
   - c. Knights Landing to Sacramento
7. Feather River
8. Yuba River
9. Bear River
10. Colusa Basin Drain
11. Knights Landing Ridge Cut
12. Cache Creek
13. Putah Creek
14. American River
    - a. Folsom Lake
    - b. Lower American River
15. City of Sacramento
    - a. American River
    - b. Sacramento River
16. Cosumnes River
17. Mokelumne River

FIGURE 3.11 (a)

SURFACE WATER DIVERSIONS
IN
SACRAMENTO VALLEY



DIVERSION POINTS

18. **Calaveras River**
    - a. Riparian
    - b. Stockton East WD
19. **Stanislaus River**
    - a. Riparian
    - b. Oakdale/South San Joaquin ID's
20. **Tuolumne River**
    - a. Riparian
    - b. Modesto ID
    - c. Turlock ID
21. **Merced River**
    - a. Riparian
    - b. Merced ID
22. **Delta Mendota Canal**
    - a. Canal
    - b. Mendota Pool - DSA 49
    - c. Mendota Pool - DSA 60
23. **San Luis Unit**
    - a. DSA 49
    - b. DSA 60 (Westlands)
24. **San Joaquin River**
    - a. Friant Dam to Fremont Ford
    - b. Fremont Ford to Tuolumne River
    - c. Tuolumne River to Vernalis
25. **Chowchilla ID**
    - a. Chowchilla River
    - b. Madera Canal
26. **Madera ID**
    - a. Fresno River
    - b. Madera Canal
27. **Friant Kern Canal**
28. **Kings River**
29. **Kaweah River**
30. **Tule River**
31. **Kern River**
32. **California Aqueduct**
    - a. DAU 216
    - b. Kings County
    - c. Kern County
33. **Cross Valley Canal**
    - a. Federal Contracts
    - b. State Contracts

FIGURE 3.11(b)

SURFACE WATER DIVERSIONS
IN
SAN JOAQUIN VALLEY

publishing Bulletin 23 as an annual series. These Bulletins provide one of the most comprehensive records of surface water diversions to major canals and of diversions made from the major rivers in the Central Valley. For example, river diversions are recorded according to major and minor diverters by milepost. The milepost provided information on the geographical location of diversions, a key requirement for establishing a suitable water balance for each subregion. The diversion data for 1922 and 1923 was estimated, except where data was available from another source. In 1963, DWR reformatted the reporting of the data, and changed the report name to Bulletin 130. Some of the minor diverters were eliminated, however, valuable records for major diverters continued to be published through 1968. From 1969 through 1975, much of the major stream diversion data was consolidated and nearly all of the minor stream diversions were eliminated. DWR discontinued the Bulletin 130 series starting with the 1975 water year. A very small amount of the data contained in these bulletins had been digitized prior to this study.

The USBR began publishing annual Reports of Operations in the mid 1940's. Early records were kept for Contra Costa Canal, Madera Canal, Friant-Kern Canal, and beginning in 1951, the Delta Mendota Canal. As additional USBR projects were developed, the reports became more comprehensive. All of the diversion data published by the USBR in their Reports of Operations were submitted to DWR for publication in Bulletins 23 and 130. The DWR bulletins included more detail, identifying diversions by individual diverter and corresponding canal or river milepost. The USBR reports were used to digitize data that are not available otherwise or to confirm data published in other reports.

The watermaster reports were the primary source of surface water diversion data in the Tulare basin. The Kings, Kaweah, Tule, and Kern Rivers are all administered by long standing water rights. The farmers of these extremely fertile lands in the Tulare basin have been taking full advantage of the water resources available to them from these local watersheds. None of the data had previously been digitized. A tremendous amount of effort was expended to analyze, organize and digitize the data from the following sources:

- Kings River - Daily records of Kings River entitlements, direct use, and storage have been published annually since 1927 by the Kings River Water Association (KRWA). Recorded data was also available in unpublished form for the period 1918 through 1926. The configuration of the Kings River service area has changed very little since 1918. Approximately 23 major districts (28 total) are served ranging from Alta and Consolidated Irrigation Districts to the east to locations 70 miles downstream including Tranquaility and James Irrigation Districts to the northwest and Tulare Lake Basin Water Storage District to the southwest. Presently, Kings River operations are governed by two major agreements. An agreement approved on September 10, 1963 supplementing and amending both the

Water Rights Indenture dated May 3, 1927, and Administrative Agreement dated May 3, 1927, (each of which were previously amended and supplemented June 1, 1949, in association with the Kings River Water Association). And on December 23, 1963, the Kings River Allocation Contract was implemented governing allocations of Pine Flat Reservoir storage. Regulated flows have been provided to KRWA member agencies from the Friant-Kern Canal (Central Valley Project) since 1949 and Pine Flat Reservoir since 1954.

- Kaweah River - The Kaweah River surface water diversions were obtained from the DWR Bulletin 49 series. The data is provided to DWR by Kaweah Delta Water Conservation District and the Kaweah and St. Johns River Associations. Bulletin 49 was first published in 1940 for the 1904 through 1940 period. It was subsequently published for the next twenty years in ten year intervals in 1950 and 1960. Since 1961, DWR has been publishing Bulletin 49 has been published every five years.

  Regulation of Kaweah River water has been provided since Terminus Dam began operations in 1962. The diversions by individual canals are governed by their relative water rights and priorities which have been established through appropriation, historical use, court decisions and stipulations. Approximately 25 district and ditch companies are served from the Kaweah River. The larger and more dependable part of the stream flow is diverted mainly through canals east of Visalia. Water service has also been provided by the Friant-Kern Canal since 1950 to some of the member agencies. Reporting formats for each district and ditch company have varied from year to year thus making a comprehensive compilation of data difficult. Great care was taken in evaluating each canal and ditch diversion to ensure that no double counting of water occurred.

- Tule River - The Tule River surface water diversions were obtained from Tule River Association reports for the period 1950-1980. Regulated water supplies have been provided to the service area by the Friant-Kern Canal since 1950, and by Success Dam since 1961. Very strict schedules of Tule River entitlements as set forth in the June 16, 1966 Tule River Water Diversion Schedule and Storage Agreement are binding on all member agencies. Service is provided through eight ditches to five areas including the Pioneer Water Company, the Vandalia Irrigation District, the Porterville Irrigation District, the Lower Tule River Irrigation District, the Kaweah River Association and the Tule River Association.

- Kern River - The Kern River surface water diversions were obtained from watermaster reports for the 1933 through 1978 period. Data was not as

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complete prior to 1933, but sufficient detail was available to provide reasonable estimates.

The primary mechanism for allocating Kern River water is the Miller-Haggin Agreement approved in 1888. This Agreement allocates water between the First Point of Measurement and the Second Point of Measurement. In 1900, the Shaw Decree was passed governing allocation of water among the First Point diverters. The Kern River Water Rights and Storage Agreement, approved December 31, 1962, distributes the flow between the upstream and the downstream groups. Water availability is based on the calculated natural flow of Kern River at the First Point of Measurement. Entitlements can be used directly or, in some cases, stored in Lake Isabella. Regulation of Kern River water has been provided by Lake Isabella since 1954. Controlling entities include the North Kern Water Storage District, the Kern Delta Water District, the city of Bakersfield, the Buena Vista Water Storage District and the so-called Lower River Rights.

Estimated Surface Water Diversions:

Sacramento River - Every effort was made to ensure the data be as comprehensive as possible. In some cases, key surface water diversion data was not available for portions of the study period and as such the missing data was estimated; the methodology used for each diversion where estimates were needed is discussed below.

The Sacramento River diversions for the 1976 through 1980 period were obtained from USBR reports of operations. The 1976 and 1977 diversions were available in summary format by river reach from the Sacramento Valley Water Use Survey (DWR Bulletin 168, 1978). The 1978-1980 diversions data were obtained from monthly major diverter data. (Major diverters represent about 85% of the total). Each of the major diverters was apportioned to the appropriate river reach. Total Sacramento River diversion data was also available. The remaining diversion data (minor diverters) were allocated by river reach in accordance with historic averages and added to major diversions to complete the data set.

Colusa Basin Drain - Colusa Basin Drain (CBD) diversion data for the period 1924-1965 was obtained from a 1967 USBR report, "Colusa Basin Drain Investigations" (USBR, 1967). Limited measured data was available after 1965. Water from the CBD is made available primarily from irrigation return flows from major Sacramento River diverters. Diversions made in 1922 and 1923 were assumed to be the same as 1925. The CBD diversions were consistent for the 1959 through 1965 period and thus the 1966-1980 period was estimated using similar years. Special adjustments were made for 1977.

Stony Creek - The Stony Creek Canal diversions for 1922-1951 were estimated by comparing historic Black Butte Reservoir inflow to average historic canal diversions, and using the lesser of either the average diversion or Black Butte inflow minus estimated losses. The resulting diversions were compared to precipitation for March and April and decreased when precipitation was greater than two inches.

Feather River - The Feather River diversions for years 1922 and 1923 were assumed to be the same as those made in 1925. For the period 1924 through 1969, the sum of the total diversions were reported in the DWR Water Supervision Reports. From 1970 to 1980, only Thermalito diversions were reported, plus unpublished records of the "major diverters" (DWR, 1990b). To estimate the additional diversions by a set of small "unidentified minor diverters", a comparison was made between (1) the Thermalito diversions plus the "major diverters" and (2) the total Feather River diversions for the historical period 1924-1969. It was assumed the discrepancy between these two quantities represented the "unidentified minor diverters". Hence, the "unidentified minor diverters", expressed as an average monthly percentage of the total Feather River diversions, was calculated and added to the recorded data, completing the 1920 through 1980 Feather River diversion data set.

Yuba River - The Yuba River diversions represent a combination of published, unpublished, and estimated diversion data. Years 1922 through 1925 were assumed to be the same as 1926. The diversion data for the period 1926 through 1969 was reported on the DWR Water Supervision Report, which included both major and minor diverters. For 1970 through 1980, only the major diverters were reported. The unidentified minor diverters were estimated as a percent of the major diverters. The percentage was based on the 1926-1969 average ratio of minor to major diverters.

Cache Creek - Data for surface water diversions from Cache Creek were obtained from DWR. Data was estimated for the period 1922 through 1926. Release records for 1922-1971 from Clear Lake were also obtained from DWR. As a result of tight water right conditions in the area, the releases from Clear Lake are mandated, and must satisfy specific downstream requirements (DWR, 1961). Based on the comparison of Clear Lake releases and Cache Creek diversions to DSA 65, it was concluded that the diversions were approximately 95 percent of the releases. Thus, a factor was applied to the Clear Lake releases to estimate the missing Cache Creek diversion data.

East Side Streams - Cosumnes, Mokelumne, and Calaveras Rivers - Historic surface water diversion records for these three streams were the most incomplete of any diversion data collected. Fortunately, the demand of surface water from the Cosumnes and Calaveras rivers for irrigation practices amounts to only 15 to 20 thousand acre-feet per year. Hence, any error introduced from the estimates would be minimal with respect to the broader scope of the regional analysis. For the periods when data was available (see Table 3.5), no correlation was found between the streamflow and surface water diversions. As an alternative, the average surface water diversion, based on the recorded data, was adjusted according to the consumptive use of applied water (CUAW). The adjustment factor used was based on an average ratio of CUAW for the period of missing data to the CUAW for the period when diversion data was recorded. The Mokelumne River, on the other hand, has a significant surface water diversion averaging approximately 120 thousand acre-feet per year, 85 percent of which is diverted by Woodbridge Irrigation District (WID). Data for the entire period, 1922-1980, was available for WID. Again, correlation between streamflows and diversions was poor. However, WID diversion, on a monthly basis, consistently accounted for 85 percent of the surface water diversion for the recorded period 1949-1975. Missing data was, therefore, estimated from WID diversions based on this observation.

San Joaquin River-Friant to Gravelly Ford - The diversions from Friant to Gravelly Ford prior to 1949 were estimated based on engineering judgment. After 1970, they were estimated by using average historic monthly values. The diversions from Gravelly Ford to Fremont Ford for 1922-1940 were estimated by taking average diversion for the period of 1942 - 1948 and limiting the diversion to 90% of the flow below Friant.

San Joaquin River - Fremont Ford to Vernalis - Missing historic data prior to 1959 was estimated using monthly averages. After 1970, monthly data was estimated by using annual estimates made by DWR San Joaquin District and distributed using historic monthly pattern.

Stanislaus River riparian diversions - Stanislaus riparian diversion data prior to 1958 was estimated based on engineering judgment. After 1970, monthly data was estimated by using annual estimates made by DWR San Joaquin District and distributed using historic monthly patterns with similar years.

Tuolumne River riparian diversions - Tuolumne River riparian diversion data prior to 1958 was estimated on the basis of data compiled by the USBR for water rights studies. After 1970, monthly data was estimated by using annual estimates made by DWR San Joaquin District and distributed using historic monthly patterns with similar years.

Merced River Riparian diversion - Merced River riparian diversion data prior to 1959 was estimated by using engineering judgment. After 1970, monthly data was estimated using annual estimates made by DWR San Joaquin District and using historic monthly patterns based on similar years analysis SWRCB, 1988).

Madera ID from Fresno River - Madera ID diversions from Fresno River were calculated as the minimum of the flow below Hidden Dam or the river diversion requirements computed from farm delivery requirements. The following data shows the headgate diversions and corresponding river diversions. The losses from river to headgate were estimated (Madera ID) at 40 percent.

Headgate Diversions -

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
15	2	0	0	1	5	15	35	55	65	55	35

River Diversion Requirements -

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
25	3	0	0	2	8	25	58	92	108	92	58

Chowchilla ID from Chowchilla River - Chowchilla ID was calculated as the minimum of the flow below Buchanan Dam and the diversion requirement.

Headgate Diversions -

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
9	1	0	0	1	3	9	21	33	39	33	21

River Diversion Requirements -

Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
15	2	0	0	1	5	15	35	55	65	55	35

Madera ID farm delivery requirements and estimated losses of 40 percent were provided by Madera ID. The same loss factor was used for Chowchilla. The ratio of Chowchilla ID and La Branza ID land use to Madera ID land use is approximately 60 percent. Thus, the farm delivery and the diversion requirement for Chowchilla/La Branza diversions from the Fresno River were assumed to be 60 percent of the Madera ID diversion.

Tule River - Data for surface water diversions from the Tule River were not available prior to 1950. To estimate the missing data, the historic diversion data was compared all the CUAW of the corresponding subregion. From this relationship a factor was used to adjust the average surface water diversion (the average based on the period 1950 through 1980).

Kings River - Surface water diversions from Kings River were estimated for 1979 and 1980. An analysis of the streamflow records indicated that on the average more than 95 percent of the monthly flow was diverted for irrigation practices. Because of this strong correlation, it was assumed that this same pattern occurred, in 1979 and 1980.

Kern River - Kern River diversions were estimated for the periods 1922-1932 and 1979-1980. As was the case with the Kings River, most of the Kern River flow is eventually utilized for irrigation. An analysis of the streamflow and the diversion records indicated a consistent monthly pattern of about 85 percent of the streamflow diverted prior to Isabella Reservoir (1953), and approximately 90 percent thereafter. An average of 85 percent of the monthly flow was used to estimate the diversions for 1922 through 1932, and 90 percent was assumed for 1979 and 1980.

Conveyance Systems Losses:

An investigation of conveyance system losses included a review of existing reports. In addition, information pertaining to lined and unlined canals, canal cross-sectional data, and percolation rates was compiled. There is a general lack of estimated historic system losses. In most cases, only rough approximations were provided, and for many canal systems, documented data was not available at all.

Losses were estimated for three major canal systems: the Delta Mendota Canal, the Friant-Kern Canal, and the San Luis Canal. System losses were estimated from an evaluation of diversions to the conveyance system and deliveries from the system. The system loss is expressed as a percentage of the total diversion, and is presented in Table 3.7. Due to data insufficiencies, a 12 percent loss was assumed for all other major conveyance systems. Lateral losses (occurring in the individual water district distribution systems) were not directly accounted for. Instead, lateral losses are handled internally in the soil moisture accounting algorithm of the model as part of the recharge component of the soil moisture budget.

Groundwater Pumpage Estimates:

Groundwater pumping in the Central Valley was estimated using USGS annual pumping data for 1961-1977 (based on annual energy use data), annual consumptive use of applied water, and annual surface water diversions. Additional annual groundwater pumping data for 1970-1980 was provided by the DWR San Joaquin District for the San Joaquin and Tulare Basins. It was found that on the average, there was only a 10 to 20 percent difference between the USGS and DWR pumping estimates. To be consistent, the USGS data was used throughout the Central Valley for the analysis and estimation of groundwater pumping.

Using multiple regression techniques, the USGS groundwater data was correlated with the consumptive use of applied water and surface water diversions for the period 1961-1977 for each subregion. The linear multiple regression equation used is:

$$P_y = a \cdot CUAW + b \cdot DIV + c \qquad (3.4)$$

TABLE 3.7

MAJOR CONVEYANCE SYSTEM LOSSES IN THE CENTRAL VALLEY

CONVEYANCE SYSTEM	LOSSES AS A PERCENT OF FLOW
Delta Mendota Canal	8%
San Luis Canal	6%
Friant-Kern Canal	9%
Others*	12%

* Listings of all conveyance systems included in the model are shown in Tables 3.6A-D.

where

P_y	= annual groundwater pumping estimate
CUAW	= annual consumptive use of applied water
DIV	= annual surface water diversion
a,b	= correlation coefficients
c	= constant

For the San Joaquin Valley (with the exception of DSA 49B) a linear relationship showed high correlations (see Table 3.8). However, in the Sacramento Valley, a linear correlation was not as promising, prompting an attempt to capture the nonlinearities of the relationship by applying a power function given by:

$$P_y = x(CUAW + k \cdot DIV + d)^y \tag{3.5}$$

where

k	= b/a
x,y	= correlation coefficients
d	= constant

This approach gave a much improved correlation for the Sacramento Valley region. It is important to note that the degree of nonlinearity was not large; DSA 15 exhibited the greatest nonlinearity with y = 1.65. [Note that as y tends to 1.0, the equation (3.5) approaches equation (3.4) in form].

In the Tulare Basin, good correlation was not observed between the USGS groundwater pumping data and the consumptive use of applied water and surface water diversions. This is the result of significant surface water diversions during pre-irrigation months, which is not directly related to consumptive use of applied water. As a result, annual groundwater pumping was first calculated from the deficiency between monthly consumptive use of applied water requirements and monthly surface water diversions. The equation is given as:

TABLE 3.8
ANNUAL GROUNDWATER PUMPING ESTIMATES
CENTRAL VALLEY

REGION	DATA SOURCE	EQUATION USED*	CORRELATION COEFFICIENT
DSA 58	USGS DWR REPORTS	Ratio (50% of surface water diversion)	---
DSA 10	USGS	$P_y = .17\ (CUAW-.44 \cdot DIV)^{1.30}$	.72
DSA 12	USGS	$P_y = 1.07\ (CUAW-.49 \cdot DIV)^{0.05}$	.88
DSA 15	USGS	$P_y = .01\ (CUAW - .20\ DIV)^{1.62}$	.80
DSA 69	USGS	$P_y = .08\ (CUAW-.36 \cdot DIV)^{1.39}$	.79
DSA 65	USGS	$P_y = .14(CUAW - .52 \cdot DIV)^{1.31}$	.71
DSA 70	USGS	$P_y = .21(CUAW-.12 \cdot DIV)^{1.19}$	.61
DSA 59	USGS	$P_y = CUAW/.80-DIV$	---
DSA 55	USGS	ASSUMED CONSTANT	---
DSA 49A	USGS	$P_y = 1.18 \cdot CUAW-.18 \cdot DIV-117.9$	.89
DSA 49B	USGS	$P_y = 1.99(CUAW-.32 \cdot DIV)^{.82}$	.87
DSA 49C	USGS	$P_y = .54 \cdot CUAW-.07 \cdot DIV-31.71$	.80
DSA 49D	USGS	$P_y = .95 \cdot CUAW-.47 \cdot DIV+348.00$	.86
DSA 60A	DWR (SWAM-Westland ID)	$P_y = CUAW/.85-DIV$	---
DSA 60B	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---
DSA 60C	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---
DSA 60D	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---
DSA 60E	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---
DSA 60F	USGS	$P_y = CUAW\ /.82-\ DIV$	---
DSA 60G	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---
DSA 60H	USGS	$P_y = f\ (CUAW, DIV, PVSGS)^{**}$	---

* See discussion of procedure in Groundwater Pumpage Estimates

** P_y - estimated annual groundwater pumping
CUAW - annual consumptive use of applied water
DIV - annual surface water diversion

$$P'_y=\sum_{i=1}^{12}[CUAW_i/I_e-DIV_i] \tag{3.6}$$

I_e is the irrigation efficiency and was assumed to be 60 percent for the entire Tulare Basin. This groundwater pumping estimate was then compared with the USGS groundwater pumping data and adjusted according to an average groundwater pumping factor:

$$P_y=P_f \cdot P'_y \tag{3.7}$$

where

$$P_f=\frac{1}{N}\sum_{j=1}^{N}P_{USGS_j}/P'_{yj} \tag{3.8}$$

P_{USGS} = USGS annual groundwater pumping
N = USGS annual groundwater pumping period of 17 years (1961-1977)

The results of the groundwater pumping estimates are given in the water budget tables (see Tables 3.4 a-u). It should be noted that in developing the estimates of groundwater pumping for the Central Valley, it was necessary to rely on USGS pumping data developed from power records. No attempt was made to further validate this data due to the lack of supporting information. To date, the power record approach is the most reliable source for estimating groundwater pumping practices.

Section 4

4.0 MODEL SIMULATION

4.1 MODEL RUN

The IGSM was applied to the entire Central Valley for a historic period from 1922 to 1980. The main purpose of this historic run is to validate and calibrate the model. Major input data developed for the historic run are described in the preceeding chapters. Other data required for the model included initial conditions, boundary conditions, and model parameters. Brief descriptions of the procedures used in developing these data are described below.

Initial Condition:

The water levels reflecting those in October, 1921 were initially developed using a 1912 water level map for the Sacramento Valley (DWR Bulletin 118-6, 1918) and a 1921 map for the San Joaquin Valley (DWR, Undated). The model was operated for the 10-year period from 1922 to 1932 in which hydrologic and water use conditions had not changed significantly. The final water levels were then used as the initial conditions.

Boundary Conditions:

The geologic formations surrounding the modeled area are generally impermeable bedrocks for which no flows are assumed to enter the model area. Thus, no flow boundary conditions are imposed at almost all boundary nodes. Only exception is the Delta area where stream bottom elevations are lower than the mean sea level (MSL). For those model nodes, the groundwater levels were assumed to be the MSL by specifying them as fixed head boundary conditions.

The other boundary condition utilized in the model was a small watershed boundary condition described in the model documentation. In the San Joaquin Valley, there are many small watersheds entering into the Valley. These streams are ephemeral and disappear before reaching main streams. Runoff from these watersheds were simulated and assumed to be directly discharged into the groundwater basin or main streams included in the models.

Model Parameters:

Major parameters required for the model are:

- Soil Parameters: hydraulic conductivity
  maximum available water capacity
  curve number

- Aquifer Parameter: hydraulic conductivity
  specific yield
  specific storage

- Stream Parameter: streambed hydraulic conductivity

The soil parameters were initially estimated based on County soil surveys by the SCS. The aquifer parameters were derived from the previous USGS investigation (Williamson et al, 1985). The streambed hydraulic conductivities were assumed to be 1 to 3 feet/day for perennial streams and 3 to 10 feet for ephemeral streams. All of these parameters were later adjusted through calibration.

4.2 SUMMARY OF MODEL OUTPUT DATA

CVGSM provides several types of information including:

- Soil moisture budget
- Land and Water budget
- Streamflow budget
- Groundwater budget
- Groundwater levels
- Streamflows

The water budget-data can be generated on a subregional basis or for the entire modeled area. Those for the latter case are presented in Tables 4(a) through 4(d). The descriptions of columns in the tables are as follows:

<u>Soil Moisture Budget:</u>

Rain: Precipitation over each land use area

Irrigation: Irrigation applied water

ET: "Actual" evapotranspiration - it is dependent on soil moisture conditions

DR: Direct runoff due to rainfall

Return:	Surface water return flow from agricultural and urban water use (such as tailwater, field runoff, urban indoor water use, etc.)
PERC:	Percolation from soil root zone as a result of rainfall and applied water. The unit used in the soil moisture budget is inches - quantity divided by area. The acreages for agricultural and urban areas are shown in the land and water budget.

<u>Land and Water Use Budget:</u>

Ag Acres:	Total agricultural area
Urban Acres:	Total urban area
Ag Supply:	Total amount of water supplied for agriculture.
Urban Supply:	Total amount of water supplied for urban and industrial needs.
GW Pumping:	Total groundwater pumped from the aquifer system.
SW Diversion:	Total amount of surface water diversions.
Recov. Loss:	Percolation to groundwater from canals, etc.
Non-Recov. Loss:	Evaporation losses from canals, etc.
Import:	Total amount of water imported into the boundary area.
Export:	Total amount of water exported from the boundary area.
Shortage:	Total water demand not met by surface water diversions, imports or groundwater pumping.

The amount of "water supply" in the table refers to the amount of water supply required excluding conveyance losses. For the historic run presented in this report, the respective quantities were developed based on the combination of total streamflow diversion plus groundwater pumping adjusted for conveyances losses. The quantities under "shortage" are the unmet portion of water supply requirements. The shortage would occur if 1) the quantity of simulated streamflows are less than the specified diversion and 2) the urban demand is less than the stream diversion and groundwater pumping.

The shortages shown in the table mainly occur in the areas of subregions 60E and 60H which are drained by Kaweah, Tule and Kern Rivers. They may be attributed to inaccuracies of estimated diversion data or inherent modeling error involved in streamflow simulation.

Streamflow Budget:

Upstream Flow:	Amount of surface water flow entering the boundary. It also includes tributary flows specified by the user.
Trib. Flow:	Small stream tributary flows entering the main streams as simulated by the model.
D.R. from Rain:	Direct runoff entering the stream system from rainfall.
Ag/Urban SW Return:	Agricultural and urban surface water return flows entering the stream system.
Gain from GW:	Gain to the streamflows from the aquifer system. If negative, it indicates streamflow loss.
SW Diversion:	Surface water diversions which remove water from the stream system.
By-pass Flow:	Bypass diversion from one stream system to another stream system.
Error Adjust:	Streamflow adjustments made for error correction for projection runs if the option is exercised.
Downstream Flow:	Amount of surface water flow leaving the boundary.
Diversion Short:	Amount of specified diversions not satisfied by streamflow.

Groundwater Budget:

Deep Perc:	Amount of water percolating through the top soil and entering the unsaturated zone.
Net Deep Perc:	Amount of water percolating through the unsaturated zone and entering the aquifer.

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TABLE 4.1(a)

SOIL MOISTURE BUDGET IN INCHES FOR ENTIRE MODEL AREA
TOTAL AREA: 12614499. ACRES

	AGRICULTURAL AREA						MUNICIPAL AREA						UNDEVELOPED AREA			
TIME	RAIN	IRIG.	ET	D.R.	RETURN	PERC.	RAIN	IRIG.	ET	D.R.	RETURN	PERC.	RAIN	ET	D.R.	PERC.
1922	12.7	43.4	38.3	2.8	2.6	12.5	14.4	22.9	16.1	7.3	12.1	1.8	14.1	9.3	2.1	2.7
1923	11.9	44.5	38.3	2.7	2.6	12.6	14.4	23.1	16.3	6.7	12.2	2.2	14.0	9.7	1.1	3.2
1924	5.3	43.6	37.3	0.4	2.6	8.9	6.4	23.4	14.4	2.4	12.3	0.7	6.2	5.1	0.1	1.0
1925	13.0	42.0	38.1	2.7	2.5	11.4	15.5	22.3	17.1	7.2	11.7	1.7	15.5	11.3	1.6	2.7
1926	9.5	44.9	38.0	2.0	2.7	11.7	11.8	22.7	15.7	5.4	12.0	1.4	11.6	8.2	1.1	2.3
1927	12.8	45.0	38.5	3.2	2.7	13.2	15.2	22.4	16.4	7.6	11.8	1.8	15.2	10.0	2.3	3.0
1928	9.6	44.5	38.2	1.9	2.6	11.4	11.2	22.8	15.9	4.8	12.0	1.3	11.7	8.7	0.8	2.2
1929	8.4	44.7	37.8	1.2	2.6	11.4	9.5	23.4	15.6	3.8	12.3	1.1	9.8	7.7	0.3	1.8
1930	8.9	45.0	37.8	1.6	2.7	11.6	10.6	23.4	15.5	5.0	12.3	1.2	10.6	7.5	1.3	1.7
1931	7.7	44.0	38.2	1.0	2.7	10.3	8.9	23.3	15.5	3.4	12.3	1.0	8.7	6.9	0.2	1.5
1932	11.4	47.1	38.3	2.5	2.8	14.7	12.8	22.9	15.9	5.8	12.0	2.0	12.7	8.7	1.1	2.8
1933	7.5	46.8	38.0	1.2	2.8	12.4	8.7	23.4	15.0	3.5	12.3	1.1	8.3	6.2	0.3	1.8
1934	7.2	46.3	38.1	1.5	2.8	11.3	8.7	23.3	14.7	3.9	12.3	1.1	8.6	6.1	0.8	1.7
1935	15.2	43.0	38.5	3.9	2.6	12.9	17.4	21.8	16.8	8.8	11.4	2.0	17.1	11.6	2.3	3.2
1936	12.5	46.4	38.5	3.0	2.7	14.6	14.7	22.7	16.5	7.3	11.9	1.7	14.3	9.7	1.9	2.7
1937	13.8	46.7	38.6	3.7	2.8	15.1	16.2	22.6	16.2	9.0	11.9	1.7	15.3	9.7	2.9	2.7
1938	17.4	47.2	38.8	6.0	2.8	16.9	19.9	22.4	16.8	11.5	11.8	2.2	19.8	11.4	4.9	3.6
1939	7.9	46.6	38.7	0.9	2.8	12.5	9.3	23.0	15.7	3.3	12.1	1.1	8.6	7.2	0.1	1.3
1940	13.6	45.8	38.4	4.1	2.7	13.7	16.2	23.2	15.9	9.0	12.2	2.2	15.6	8.6	3.8	3.2
1941	19.3	43.4	38.9	6.6	2.6	14.4	22.2	22.3	17.1	12.4	11.7	3.1	23.4	12.2	6.3	4.9
1942	14.1	44.7	39.0	4.0	2.7	13.2	16.6	22.4	16.8	8.4	11.8	2.0	16.8	10.8	2.9	3.0
1943	12.2	46.5	39.2	3.1	2.8	13.5	14.5	22.9	16.3	7.3	12.0	1.8	14.2	9.5	1.9	2.8
1944	9.8	47.4	39.2	2.0	2.9	13.1	11.2	23.5	16.0	5.1	12.4	1.2	11.0	8.2	0.9	1.9
1945	11.3	46.8	39.2	2.6	2.8	13.2	13.1	23.2	16.5	6.1	12.2	1.6	13.4	9.6	1.2	2.6
1946	10.0	48.1	39.2	2.2	2.9	13.7	11.7	23.4	16.2	5.0	12.3	1.6	12.2	8.8	0.7	2.6
1947	7.8	47.0	39.0	1.2	2.8	11.8	9.0	23.7	15.6	3.5	12.5	1.0	9.6	7.5	0.2	1.9
1948	9.9	41.8	38.4	1.6	2.5	9.0	11.7	22.9	16.5	4.6	12.1	1.4	12.5	10.1	0.3	2.2
1949	8.2	45.7	38.8	1.4	2.7	10.9	9.8	23.8	15.6	4.3	12.5	1.1	10.5	7.7	0.8	2.0
1950	8.7	45.8	39.0	1.5	2.7	11.0	10.5	23.5	15.8	4.6	12.4	1.2	10.2	7.6	0.9	1.7
1951	10.9	45.6	39.3	2.8	2.7	11.6	13.9	23.4	16.3	6.8	12.3	1.9	13.9	9.5	1.7	2.7
1952	15.2	43.1	39.5	4.3	2.6	11.6	18.0	23.1	17.0	9.4	12.1	2.6	18.3	11.0	3.4	3.9
1953	10.2	45.6	39.7	2.2	2.7	11.2	12.2	23.7	16.1	5.3	12.5	2.0	13.3	8.7	1.3	3.3
1954	9.1	45.4	39.5	1.5	2.7	10.6	10.8	23.4	16.1	4.6	12.3	1.1	11.3	8.5	0.7	2.1
1955	10.2	44.3	39.3	2.1	2.7	10.4	12.1	23.7	16.0	5.5	12.5	1.8	12.0	8.4	1.0	2.5
1956	13.8	44.2	38.9	4.3	2.6	12.0	17.1	23.4	16.1	8.7	12.4	3.3	17.7	9.2	3.7	4.7
1957	8.3	44.0	38.4	1.1	2.6	10.2	10.7	23.0	16.2	4.2	12.2	1.1	10.6	8.6	0.3	1.7
1958	19.0	36.9	38.4	5.8	2.2	9.4	23.0	21.7	18.0	13.1	11.4	2.1	24.1	14.0	6.2	3.8
1959	7.4	45.8	38.1	1.5	2.7	10.8	10.0	23.6	15.4	4.5	12.5	1.2	9.9	7.0	1.1	1.8
1960	6.9	44.7	38.0	1.1	2.7	10.0	9.1	23.7	15.2	4.1	12.5	1.0	9.4	6.8	1.0	1.7
1961	8.6	43.3	38.1	1.7	2.6	9.7	10.8	23.0	15.7	4.9	12.1	1.2	11.8	8.3	1.2	2.3
1962	11.0	45.4	38.2	2.7	2.7	12.5	13.5	23.0	15.8	6.8	12.0	1.9	13.7	8.8	1.7	3.2
1963	13.0	42.2	38.0	3.0	2.5	11.6	17.2	21.8	17.2	8.5	11.4	1.7	16.8	11.8	2.1	2.8
1964	7.4	43.8	38.0	1.0	2.6	9.9	9.8	23.0	15.6	3.8	12.1	1.2	9.5	7.4	0.2	1.8
1965	11.3	43.8	38.1	2.2	2.6	12.1	15.2	22.3	16.5	7.0	11.7	2.3	15.0	10.4	1.4	3.2
1966	8.2	43.9	38.1	1.4	2.6	10.2	10.3	23.3	15.3	4.8	12.2	1.4	10.7	7.3	1.1	2.3
1967	15.6	41.5	38.0	4.2	2.4	11.9	20.3	21.8	16.9	10.9	11.4	2.8	19.5	11.5	4.1	3.9
1968	8.4	41.3	38.0	1.5	2.5	8.5	11.1	22.8	15.8	4.9	11.9	1.2	11.1	8.0	1.1	1.9
1969	18.7	40.5	37.8	5.7	2.4	12.5	23.2	22.3	16.7	13.7	11.7	3.3	21.9	11.1	5.8	5.0
1970	10.3	41.3	37.4	2.6	2.4	9.5	14.6	22.9	15.7	7.7	12.0	2.1	14.4	8.2	3.1	3.1
1971	10.3	40.1	37.5	2.3	2.4	8.3	14.4	22.6	16.0	6.8	11.9	2.3	14.2	9.4	2.0	2.9
1972	5.5	41.9	37.0	0.6	2.5	7.6	8.1	23.0	15.0	3.1	12.1	1.0	7.7	6.1	0.2	1.4
1973	15.6	39.7	37.0	4.9	2.4	10.1	20.1	22.0	16.2	11.9	11.5	2.5	20.5	10.5	5.6	4.3
1974	12.0	40.0	37.0	3.2	2.4	9.6	17.4	21.6	16.6	8.8	11.3	2.4	17.3	10.9	3.1	3.3
1975	11.1	39.9	37.0	2.5	2.4	9.2	14.5	21.7	16.1	7.1	11.3	1.6	14.6	9.9	2.3	2.5
1976	7.1	40.8	36.0	0.7	2.5	8.7	8.5	21.8	15.0	2.9	11.4	0.9	8.4	7.2	0.0	1.1
1977	5.9	35.7	34.9	0.4	2.1	4.9	7.0	22.0	14.4	2.4	11.5	0.7	7.4	6.5	0.0	0.9
1978	19.5	33.1	35.4	5.6	2.0	8.5	23.7	20.6	16.8	14.2	10.7	2.6	24.1	12.5	7.2	4.4
1979	10.9	40.1	35.8	2.6	2.4	10.1	14.0	21.3	15.4	7.1	11.0	1.7	14.0	9.0	2.4	2.7
1980	14.0	39.0	36.0	4.1	2.3	10.6	18.1	20.8	16.2	9.7	10.8	2.2	18.3	10.9	3.8	3.5
AVERAGE	11.1	43.6	38.1	2.6	2.6	11.3	13.6	22.8	16.0	6.6	12.0	1.7	13.6	9.0	1.9	2.6

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TABLE 4.1(b)

LAND AND WATER USE IN 1000 AF FOR ENTIRE MODEL AREA
TOTAL AREA: 12614499. ACRES

TIME	AG 1000 AC	URBAN 1000 AC	AG SUP. REQ. (+)	URBAN SUP. REQ. (+)	GW PUMPING (-)	SW DIVERSION (-)	RECOV. LOSS (+)	NON-REC. LOSS (+)	IMPORT (-)	EXPORT (+)	SHORTAGE (=)
1922	2771.	95.	10013.	181.	4651.	[illegible]	503.	147.	784.	83.	18.
1923	2782.	97.	10324.	187.	5334.	5021.	474.	138.	826.	83.	25.
1924	2806.	102.	10203.	198.	7045.	3208.	239.	88.	520.	75.	30.
1925	2814.	104.	9852.	194.	5244.	4609.	410.	132.	770.	83.	47.
1926	2853.	108.	10674.	204.	6124.	4560.	351.	130.	716.	81.	39.
1927	2885.	111.	10812.	208.	4925.	6013.	575.	167.	867.	74.	31.
1928	2925.	113.	10845.	214.	6296.	4553.	393.	127.	786.	92.	35.
1929	2982.	115.	11118.	225.	6257.	4887.	404.	139.	775.	89.	55.
1930	2991.	119.	11205.	232.	6111.	5169.	406.	144.	762.	99.	44.
1931	2942.	123.	10793.	238.	6692.	4207.	256.	117.	568.	109.	46.
1932	2924.	128.	11484.	244.	4838.	6922.	638.	196.	846.	96.	52.
1933	2928.	131.	11424.	255.	5765.	5780.	501.	160.	840.	103.	58.
1934	2906.	134.	11212.	261.	6723.	4640.	353.	129.	655.	105.	43.
1935	2898.	138.	10373.	251.	4447.	6059.	549.	169.	899.	97.	34.
1936	2929.	141.	11335.	266.	4677.	7055.	797.	197.	927.	110.	46.
1937	2986.	144.	11613.	272.	4575.	7909.	1237.	207.	910.	96.	31.
1938	2913.	147.	11450.	274.	4063.	8321.	1376.	209.	972.	92.	46.
1939	2905.	151.	11271.	290.	5578.	5958.	543.	167.	785.	102.	53.
1940	3025.	154.	11533.	298.	5014.	7104.	883.	194.	840.	91.	40.
1941	3137.	162.	11351.	300.	4406.	8017.	1359.	206.	861.	102.	35.
1942	3247.	169.	12107.	316.	5200.	7495.	943.	205.	926.	90.	39.
1943	3334.	177.	12924.	338.	5628.	8236.	1259.	218.	946.	106.	35.
1944	3454.	184.	13645.	360.	6465.	7442.	705.	211.	1087.	117.	43.
1945	3619.	190.	14108.	368.	5939.	8574.	947.	237.	1217.	114.	43.
1946	3788.	197.	15180.	384.	7166.	8266.	740.	234.	1190.	125.	41.
1947	3974.	205.	15553.	403.	8732.	6988.	557.	200.	1055.	116.	55.
1948	4170.	211.	14520.	402.	8273.	6348.	468.	183.	1008.	106.	51.
1949	4365.	220.	16620.	436.	9563.	7144.	476.	208.	1113.	144.	64.
1950	4395.	232.	16764.	455.	9146.	7678.	569.	221.	1212.	145.	117.
1951	4618.	237.	17538.	462.	9595.	7979.	663.	231.	1409.	137.	48.
1952	4725.	243.	16969.	466.	7434.	10224.	1419.	275.	1562.	141.	50.
1953	4827.	249.	18344.	493.	9567.	8370.	665.	243.	1876.	126.	58.
1954	4909.	257.	18569.	502.	9641.	8273.	576.	242.	2050.	145.	70.
1955	5034.	267.	18567.	526.	10215.	7572.	494.	222.	2114.	159.	67.
1956	5223.	277.	19255.	542.	9022.	9382.	782.	268.	2534.	160.	70.
1957	5391.	286.	19758.	548.	10812.	7989.	606.	231.	2414.	158.	85.
1958	5600.	296.	17218.	535.	7707.	8633.	714.	244.	2424.	129.	76.
1959	5656.	305.	21592.	601.	12562.	8166.	548.	229.	2326.	167.	82.
1960	5712.	314.	21257.	619.	12920.	7602.	422.	219.	2085.	175.	86.
1961	5777.	325.	20854.	624.	13573.	6569.	322.	192.	1919.	165.	95.
1962	5844.	333.	22107.	639.	11833.	9045.	655.	268.	2875.	173.	88.
1963	5916.	340.	20811.	616.	11247.	8109.	630.	240.	2969.	124.	97.
1964	5985.	348.	21862.	667.	12919.	8001.	591.	228.	2455.	152.	124.
1965	6046.	356.	22085.	662.	11715.	8875.	711.	260.	3150.	153.	131.
1966	6126.	364.	22399.	707.	13028.	8231.	584.	236.	2756.	187.	98.
1967	6194.	372.	21408.	675.	10627.	9612.	867.	272.	3072.	159.	70.
1968	6311.	380.	21703.	723.	11928.	8755.	688.	247.	2780.	201.	99.
1969	6347.	388.	21402.	720.	10184.	10301.	876.	296.	2902.	177.	83.
1970	6381.	395.	21940.	754.	10976.	9385.	817.	266.	3522.	175.	69.
1971	6472.	408.	21612.	769.	11212.	8404.	606.	241.	3687.	192.	117.
1972	6585.	422.	22976.	809.	12522.	8161.	520.	235.	3934.	200.	122.
1973	6752.	439.	22363.	805.	10375.	9559.	703.	275.	4240.	164.	136.
1974	6966.	456.	23199.	822.	10070.	9824.	777.	280.	5209.	169.	145.
1975	7072.	475.	23502.	859.	10573.	9692.	775.	279.	5216.	188.	120.
1976	7143.	495.	24267.	899.	12820.	8668.	498.	241.	4468.	205.	153.
1977	7112.	511.	21155.	937.	15435.	4903.	241.	137.	2110.	177.	198.
1978	7199.	532.	19838.	911.	8333.	9725.	749.	278.	3769.	151.	101.
1979	7266.	553.	24254.	981.	10399.	10374.	854.	291.	5707.	177.	76.
1980	7339.	572.	23865.	990.	9470.	11424.	945.	320.	5335.	182.	74.
AVERAGE	4664.	263.	16661.	493.	8535.	7550.	665.	213.	2009.	134.	71.

TABLE 4.1(c)

STREAMFLOW BUDGET IN 1000 AF FOR ENTIRE MODEL AREA
TOTAL AREA: 12614499. ACRES

TIME	UPSTREAM FLOW (+)	TRIB. FLOW (+)	D.R. FROM RAIN (+)	AG/URBAN SW RETURN (+)	GAIN FROM GW (+)	SW DIVERSION (-)	BY-PASS FLOW (+)	ERROR ADJUST. (+)	DOWNSTRM FLOW (=)	DIVERSION SHORT
1922	32856.	186.	2374.	691.	2000.	5473.	-2174.	0.	30460.	13.
1923	23737.	38.	1576.	708.	1846.	5021.	-1471.	0.	21413.	14.
1924	8358.	1.	196.	710.	1141.	3208.	-391.	0.	6807.	30.
1925	25915.	69.	2003.	679.	839.	4609.	-850.	0.	24046.	60.
1926	18601.	32.	1412.	741.	1408.	4560.	-911.	0.	16722.	43.
1927	37342.	126.	2672.	753.	1537.	6013.	-1777.	0.	34640.	35.
1928	25297.	31.	1131.	755.	1507.	4553.	-950.	0.	23218.	27.
1929	13561.	26.	569.	776.	1429.	4887.	-421.	0.	11053.	53.
1930	19613.	54.	1523.	788.	1135.	5169.	-383.	0.	17562.	49.
1931	9313.	3.	440.	778.	1301.	4207.	-253.	0.	7375.	43.
1932	24201.	92.	1567.	810.	996.	6922.	-987.	0.	19757.	45.
1933	14994.	17.	553.	815.	1186.	5780.	-436.	0.	11349.	47.
1934	13275.	28.	1064.	807.	1174.	4640.	-304.	0.	11404.	43.
1935	27508.	195.	2890.	748.	1027.	6059.	-674.	0.	25634.	29.
1936	30775.	120.	2352.	810.	1592.	7055.	-812.	0.	27782.	42.
1937	27088.	212.	3317.	832.	2018.	7909.	-1655.	0.	23903.	13.
1938	56169.	421.	5491.	819.	2452.	8321.	-2757.	0.	54273.	30.
1939	14374.	22.	315.	832.	2012.	5958.	-771.	0.	10825.	36.
1940	36351.	224.	4114.	841.	2048.	7104.	-1284.	0.	35190.	23.
1941	46230.	477.	6807.	831.	2877.	8017.	-2229.	0.	46977.	15.
1942	41398.	151.	3414.	884.	2732.	7495.	-1342.	0.	39741.	14.
1943	37012.	88.	2417.	952.	2816.	8236.	-1891.	0.	33159.	10.
1944	16896.	44.	1337.	1010.	2423.	7442.	-920.	0.	13349.	21.
1945	25791.	68.	1789.	1040.	2500.	8574.	-1411.	0.	21203.	10.
1946	28508.	24.	1314.	1112.	2568.	8266.	-1136.	0.	24124.	11.
1947	16649.	10.	608.	1142.	1928.	6988.	-783.	0.	12565.	25.
1948	21914.	0.	812.	1071.	1365.	6348.	-583.	0.	18231.	25.
1949	18780.	26.	1102.	1223.	1568.	7144.	-545.	0.	15010.	42.
1950	22242.	36.	1204.	1241.	1165.	7678.	-633.	0.	17577.	97.
1951	36966.	55.	2320.	1290.	1092.	7979.	-879.	0.	32867.	18.
1952	47356.	221.	4065.	1259.	1492.	10224.	-1655.	0.	42514.	17.
1953	28459.	31.	1805.	1359.	1596.	8370.	-760.	0.	24120.	27.
1954	25610.	34.	1160.	1376.	1188.	8273.	-682.	0.	20414.	40.
1955	16558.	44.	1629.	1397.	1057.	7572.	-747.	0.	12366.	37.
1956	45719.	192.	4266.	1431.	1056.	9382.	-1380.	0.	41902.	40.
1957	21587.	12.	810.	1455.	895.	7989.	-725.	0.	16045.	59.
1958	45885.	453.	6536.	1301.	741.	8633.	-1564.	0.	44720.	37.
1959	18791.	25.	1416.	1603.	1054.	8166.	-614.	0.	14109.	60.
1960	16799.	14.	1164.	1592.	524.	7602.	-351.	0.	12140.	70.
1961	15683.	30.	1622.	1566.	278.	6569.	-272.	0.	12337.	64.
1962	21740.	155.	2442.	1635.	30.	9045.	-781.	0.	16176.	55.
1963	32584.	157.	2842.	1534.	128.	8109.	-883.	0.	28252.	81.
1964	17934.	0.	748.	1645.	268.	8001.	-409.	0.	12185.	93.
1965	37787.	25.	2070.	1634.	-294.	8875.	-601.	0.	31747.	119.
1966	21737.	42.	1433.	1698.	-36.	8231.	-510.	0.	16134.	58.
1967	41843.	233.	4553.	1596.	-458.	9612.	-2374.	0.	35781.	30.
1968	21363.	28.	1518.	1682.	228.	8755.	-626.	0.	15438.	73.
1969	48786.	511.	6299.	1641.	-115.	10301.	-5100.	0.	41721.	59.
1970	37760.	99.	3177.	1694.	465.	9385.	-902.	0.	32907.	41.
1971	31736.	35.	2395.	1686.	-162.	8404.	-358.	0.	26929.	99.
1972	20168.	2.	504.	1797.	-243.	8161.	-233.	0.	13835.	121.
1973	31360.	359.	5709.	1747.	-713.	9559.	-547.	0.	28355.	136.
1974	47728.	112.	3509.	1801.	-608.	9824.	-571.	0.	42149.	153.
1975	30341.	86.	2745.	1848.	-400.	9692.	-500.	0.	24427.	105.
1976	18511.	3.	532.	1950.	-387.	8668.	-312.	0.	11628.	160.
1977	10154.	0.	360.	1764.	-905.	4903.	-210.	0.	6259.	195.
1978	30990.	482.	6905.	1662.	-2326.	9725.	-1903.	0.	26085.	71.
1979	23369.	125.	2839.	1943.	-596.	10374.	-886.	0.	16420.	48.
1980	39615.	198.	4436.	1924.	-563.	11424.	-1343.	0.	32843.	57.
AVERAGE	27452.	112.	2342.	1249.	930.	7550.	-1007.	0.	23528.	54.

TABLE 4.1(d)

GROUND WATER BUDGET IN 1000 AF FOR ENTIRE MODEL AREA
TOTAL AREA: 12614499. ACRES

TIME	DEEP PERC.	NET DEEP PERC. (+)	GAIN FROM STREAM (+)	RECHARGE (+)	OTHER INFLOW (+)	SUBSURF. INFLOW (+)	PUMPING (-)	CHANGE IN STORAGE (=)	END STORAGE M. AF
1922	5133.	5115.	-2000.	1358.	0.	3001.	4651.	2823.	1821.4
1923	5541.	5539.	-1846.	1143.	0.	2052.	5334.	1554.	1823.0
1924	2915.	2920.	-1141.	475.	0.	797.	7045.	-3995.	1819.0
1925	4845.	4845.	-839.	901.	0.	1749.	5244.	1412.	1820.4
1926	4619.	4618.	-1408.	860.	0.	1391.	6124.	-662.	1819.7
1927	5564.	5565.	-1537.	1380.	0.	2564.	4925.	3046.	1822.8
1928	4545.	4547.	-1507.	889.	0.	1410.	6296.	-957.	1821.8
1929	4288.	4288.	-1429.	632.	0.	1371.	6257.	-1394.	1820.4
1930	4269.	4267.	-1135.	617.	0.	1434.	6111.	-928.	1819.5
1931	3742.	3743.	-1301.	399.	0.	1095.	6692.	-2756.	1816.7
1932	5851.	5851.	-996.	1095.	0.	2540.	4838.	3652.	1820.4
1933	4481.	4480.	-1186.	702.	0.	1466.	5765.	-303.	1820.1
1934	4112.	4115.	-1174.	481.	0.	1124.	6723.	-2176.	1817.9
1935	5707.	5705.	-1027.	903.	0.	3277.	4447.	4411.	1822.3
1936	5713.	5714.	-1592.	1128.	0.	2476.	4677.	3049.	1825.4
1937	5947.	5946.	-2018.	1772.	0.	3136.	4575.	4261.	1829.6
1938	6983.	6982.	-2452.	1978.	0.	4072.	4063.	6518.	1836.2
1939	4099.	4103.	-2012.	804.	0.	1200.	5578.	-1483.	1834.7
1940	6038.	6038.	-2048.	1288.	0.	3032.	5014.	3296.	1838.0
1941	7621.	7618.	-2877.	1765.	0.	4249.	4406.	6349.	1844.3
1942	5917.	5922.	-2732.	1298.	0.	2383.	5200.	1671.	1846.0
1943	5919.	5916.	-2816.	1613.	0.	2189.	5628.	1274.	1847.3
1944	5253.	5256.	-2423.	1005.	0.	1605.	6465.	-1021.	1846.2
1945	5908.	5905.	-2500.	1394.	0.	2129.	5939.	990.	1847.2
1946	6263.	6263.	-2568.	1146.	0.	1572.	7166.	-753.	1846.5
1947	5221.	5221.	-1928.	885.	0.	1308.	8732.	-3245.	1843.2
1948	4658.	4657.	-1365.	753.	0.	1184.	8273.	-3044.	1840.2
1949	5363.	5362.	-1568.	761.	0.	1253.	9563.	-3756.	1836.4
1950	5208.	5208.	-1165.	868.	0.	1497.	9146.	-2738.	1833.7
1951	6256.	6255.	-1092.	1089.	0.	1811.	9595.	-1533.	1832.2
1952	7091.	7088.	-1492.	1939.	0.	3216.	7434.	3317.	1835.5
1953	6639.	6640.	-1596.	1013.	0.	1779.	9567.	-1731.	1833.7
1954	5680.	5680.	-1188.	959.	0.	1436.	9641.	-2754.	1831.0
1955	5953.	5953.	-1057.	934.	0.	1925.	10215.	-2461.	1828.5
1956	8054.	8049.	-1056.	1409.	0.	3238.	9022.	2618.	1831.2
1957	5595.	5588.	-895.	961.	0.	1128.	10812.	-4029.	1827.1
1958	6563.	6557.	-741.	1390.	0.	4039.	7707.	3538.	1830.7
1959	6096.	6093.	-1054.	911.	0.	1136.	12562.	-5475.	1825.2
1960	5677.	5678.	-524.	651.	0.	1184.	12920.	-5932.	1819.3
1961	5931.	5930.	-278.	608.	0.	1413.	13573.	-5899.	1813.4
1962	7836.	7811.	-30.	1173.	0.	2801.	11833.	-78.	1813.3
1963	7256.	7264.	-128.	1166.	0.	2025.	11247.	-919.	1812.4
1964	5916.	5921.	-268.	935.	0.	988.	12919.	-5343.	1807.0
1965	7817.	7804.	294.	1074.	0.	1919.	11715.	-624.	1806.4
1966	6384.	6386.	36.	944.	0.	1687.	13028.	-3975.	1802.4
1967	8180.	8155.	458.	2162.	0.	3085.	10627.	3233.	1805.6
1968	5446.	5484.	-228.	1137.	0.	1195.	11928.	-4340.	1801.3
1969	9165.	9120.	115.	2796.	0.	5735.	10184.	7582.	1808.9
1970	6610.	6651.	-465.	1269.	0.	1884.	10976.	-1636.	1807.3
1971	5924.	5917.	162.	844.	0.	1653.	11212.	-2637.	1804.6
1972	4848.	4853.	243.	677.	0.	844.	12522.	-5907.	1798.7
1973	7734.	7684.	713.	1036.	0.	3371.	10375.	2428.	1801.1
1974	7059.	7073.	608.	1108.	0.	2126.	10070.	845.	1802.0
1975	6502.	6500.	400.	1031.	0.	1748.	10573.	-895.	1801.1
1976	5709.	5704.	387.	749.	0.	1060.	12820.	-4920.	1796.2
1977	3300.	3299.	905.	539.	0.	832.	15435.	-9860.	1786.3
1978	7036.	7029.	2326.	2019.	0.	4997.	8333.	8038.	1794.3
1979	7280.	7248.	596.	1409.	0.	2112.	10399.	966.	1795.3
1980	7998.	7989.	563.	1669.	0.	2570.	9470.	3322.	1798.6
AVERAGE	5920.	5917.	-930.	1117.	0.	2093.	8535.	-338.	1798.6

Gain from Stream:	Amount of water lost from streams that enters the aquifer system. If negative, it indicates that groundwater enters steams resulting in streamflow gain.
Recharge:	Artificial recharge or any recharge estimated separately from the model and specified by the user. It also include recharge contributed from canal seepage.
Other Inflow:	Seepage through bedrock and lakes.
Subsurface Inflow:	Includes net boundary flux. If negative groundwater is flowing out of the boundary.
Change in Storage:	Change in aquifer storage.
End Storage:	Total final storage of aquifer system.

The aquifer storage shown in the table includes water stored in all layers and are computed based on saturated thicknesses and storage coefficients.

4.3 CALIBRATION

The model was calibrated by comparing its results with groundwater levels measured at selected wells (locations shown in Figure 4.1) from 1970 to 1980 and streamflow data available for the entire simulation period. The water level data were provided by the DWR. The streamflow data used for calibration purposes were based on those streamflow data developed as basin outflows for the DSA's by the DWR.

A comparison of simulated and measured groundwater level elevations is presented in Figures 4.2(a) through 4.2(aq). In general, simulated water levels were found to be in reasonable agreement with measured water levels throughout the model area.

Discrepancies between observed and predicted water levels might be attributed to the following reasons:

> Modeling Error: The simulation model developed represents physical processes by a series of mathematical formulas. Due to the complicated or random nature of the physical process, a mathematical representation is never possible without introducing certain assumptions. For example, the grid size used in the model averages 14 square miles. Although appropriate for this study, the grid size is fairly large as compared to the rate of the groundwater movement and its response to natural and man-

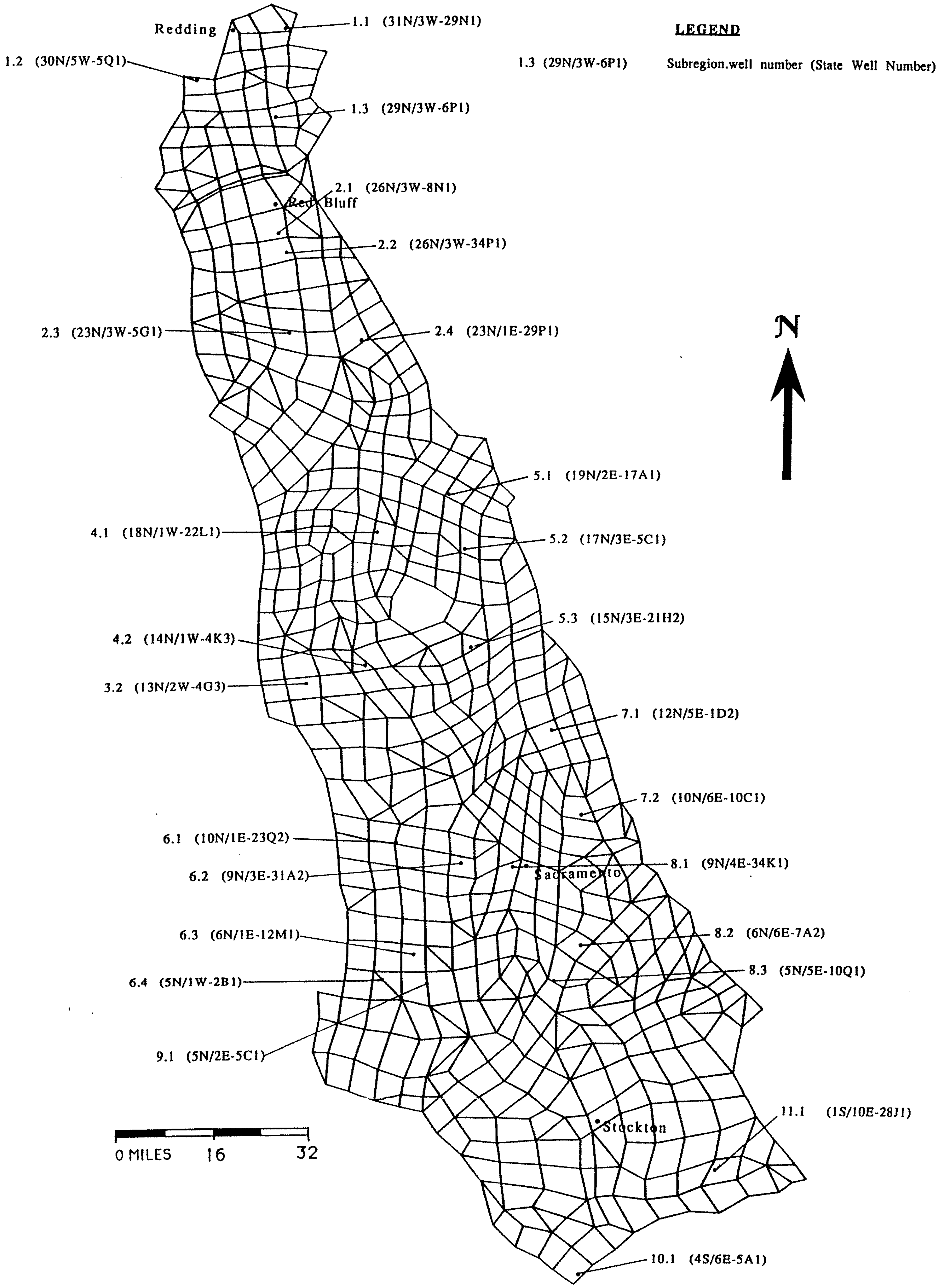

FIGURE 4.1(a)

CALIBRATION WELL LOCATIONS
IN
SACRAMENTO VALLEY

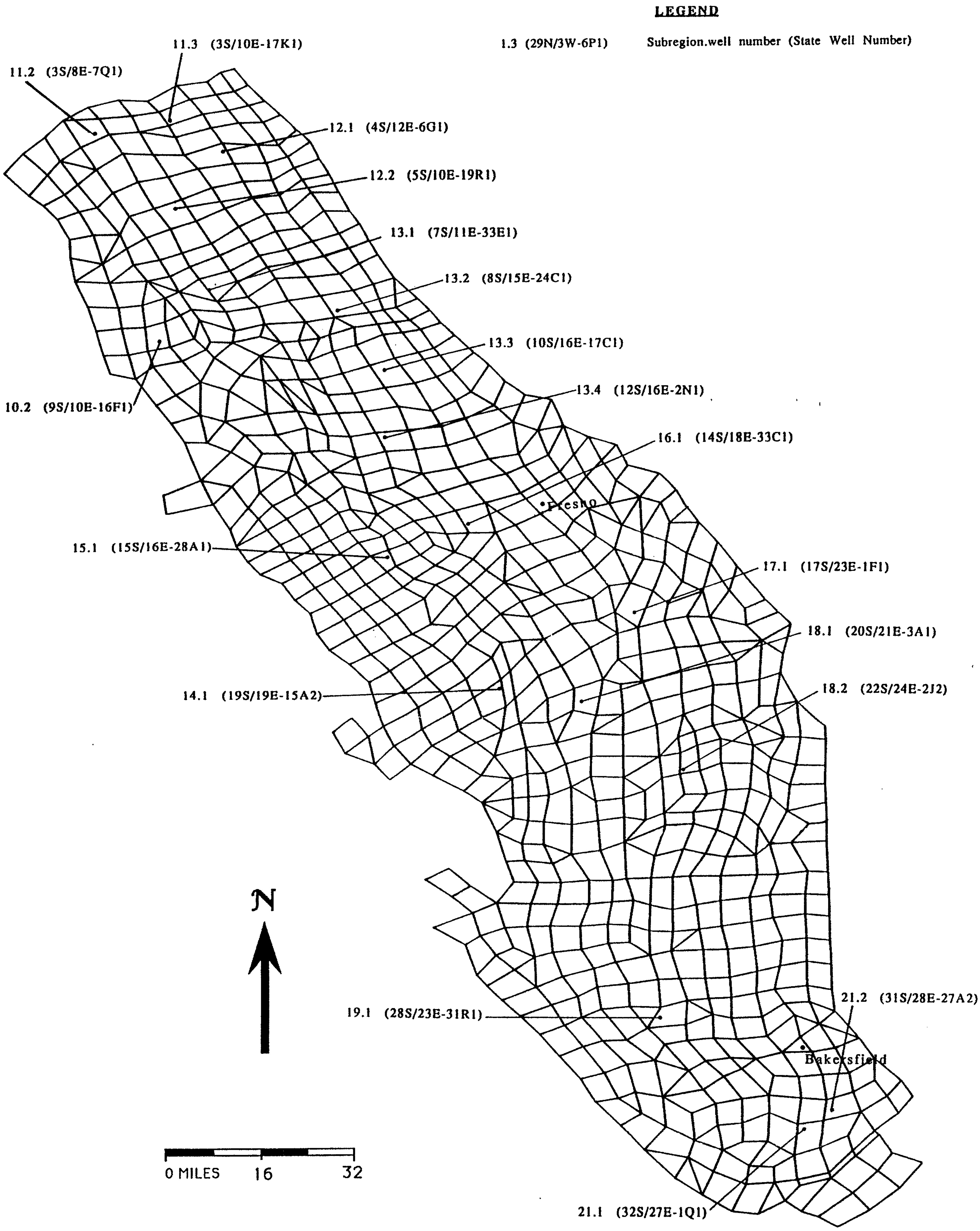

FIGURE 4.1(b)

CALIBRATION WELL LOCATIONS
IN
SAN JOAQUIN VALLEY

FIGURE 4.2(a)

WELL 1.1

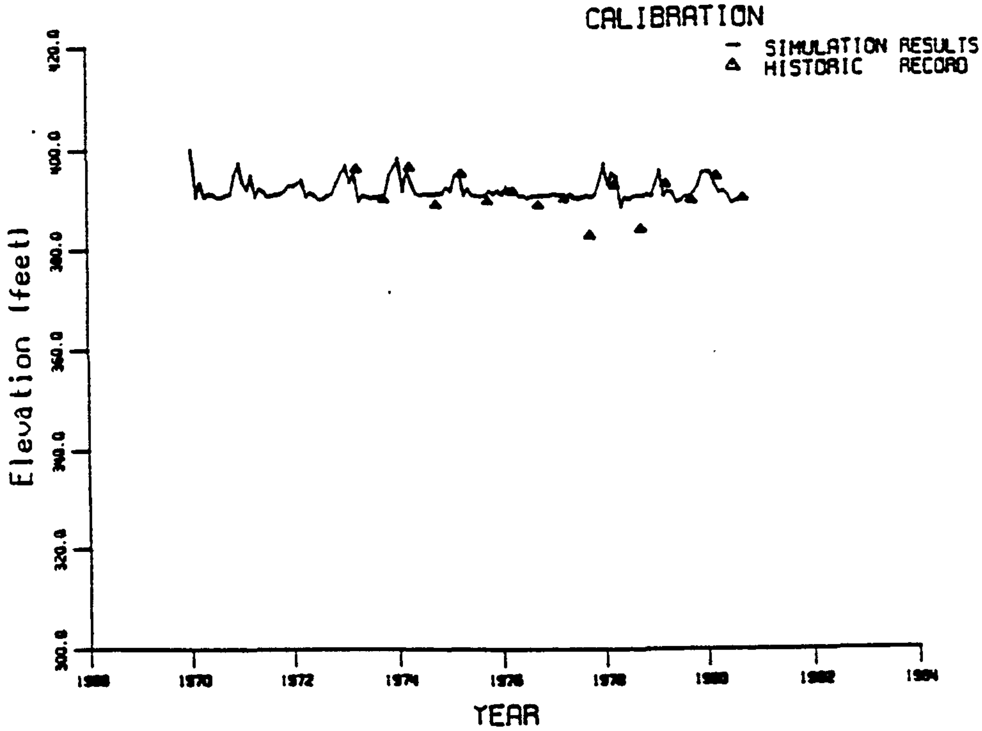

FIGURE 4.2(b)

WELL 1.2

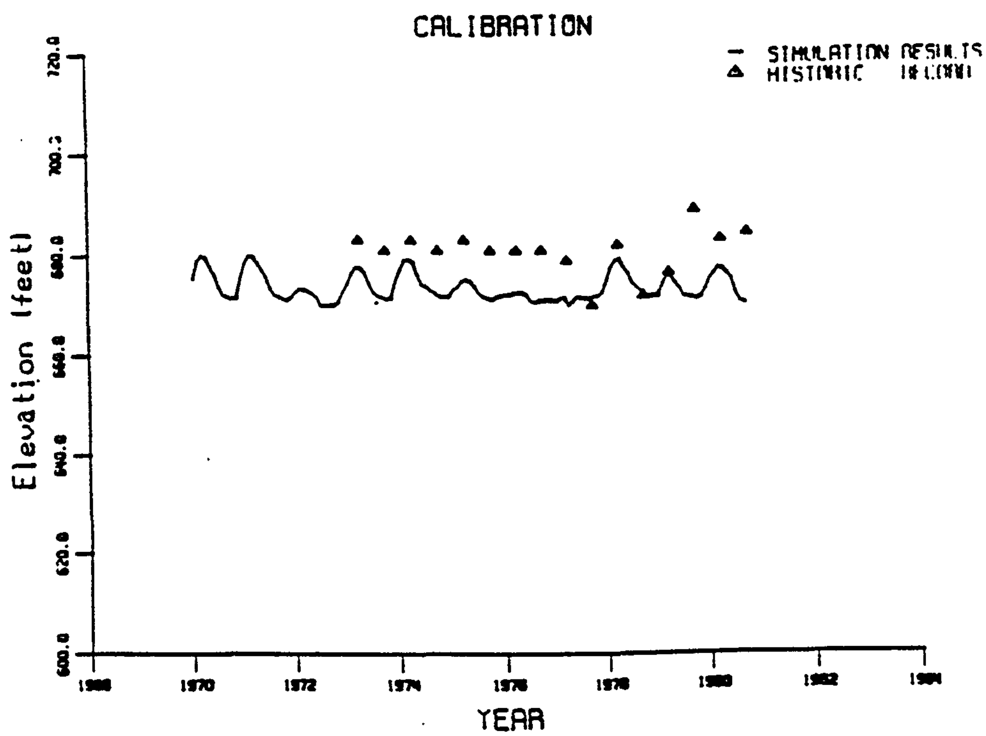

FIGURE 4.2(c)

WELL 1.3

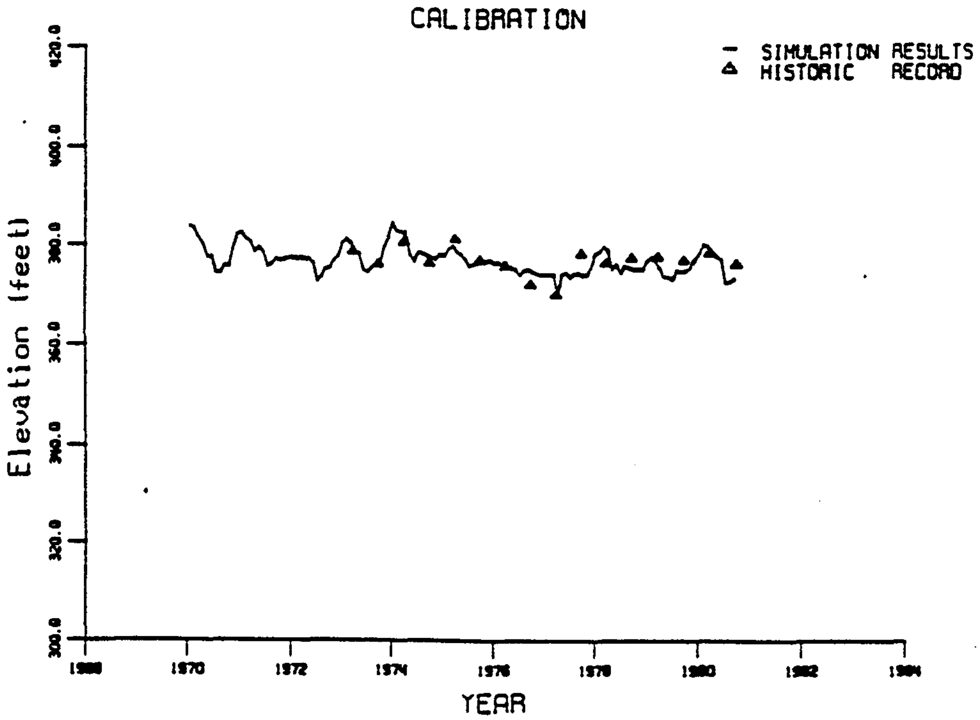

FIGURE 4.2(d)

WELL 2.1

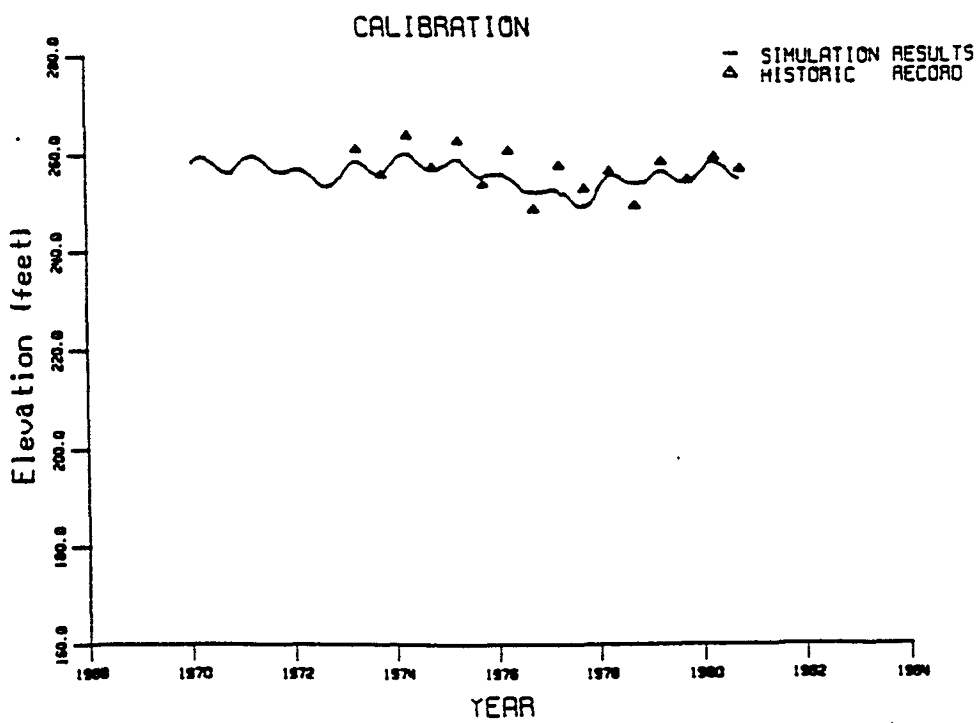

FIGURE 4.2(e)

WELL 2.2

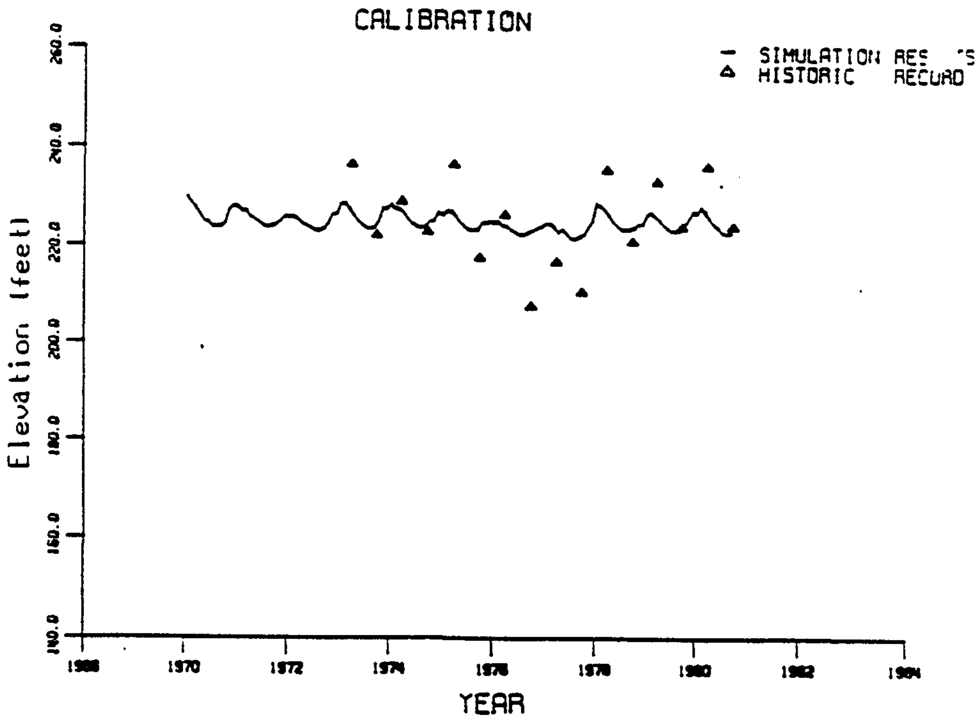

FIGURE 4.2(f)

WELL 2.3

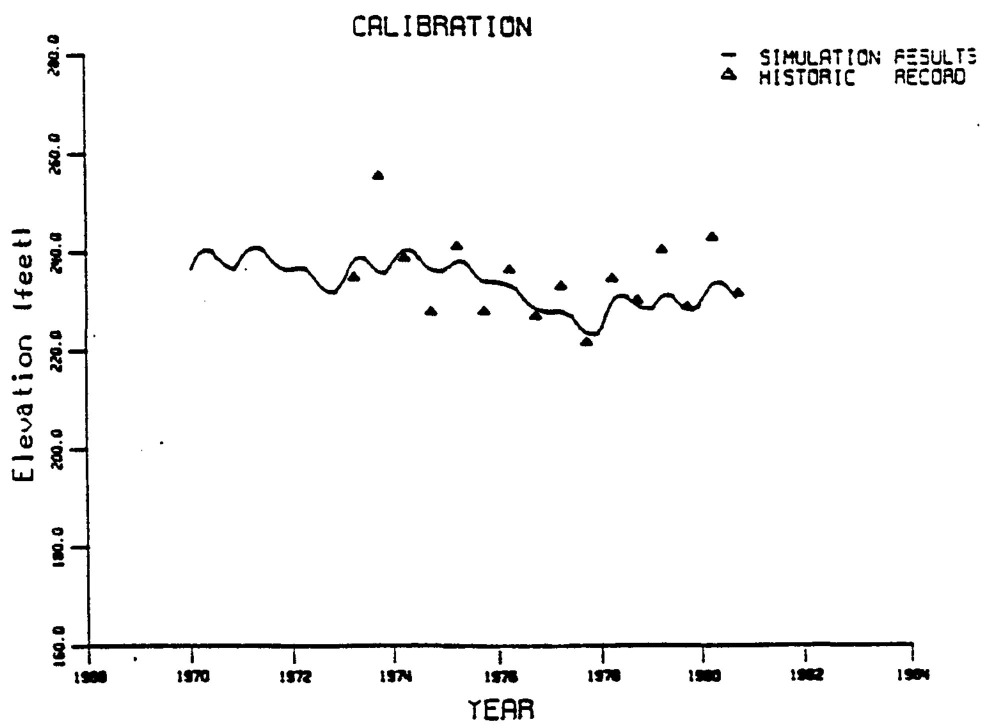

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FIGURE 4.2(g)

WELL 2.4

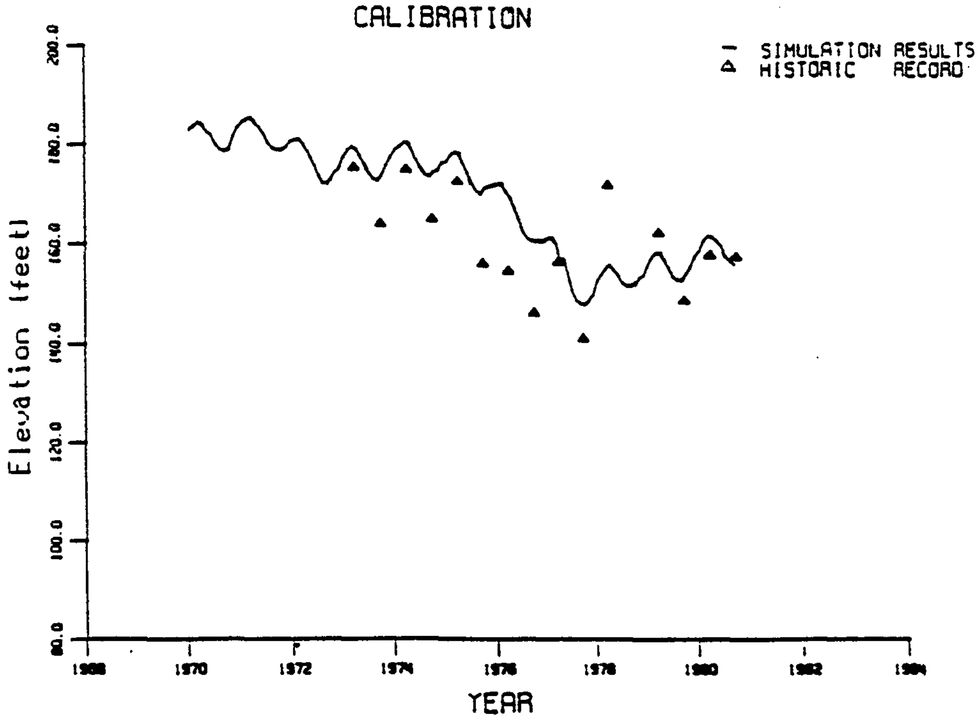
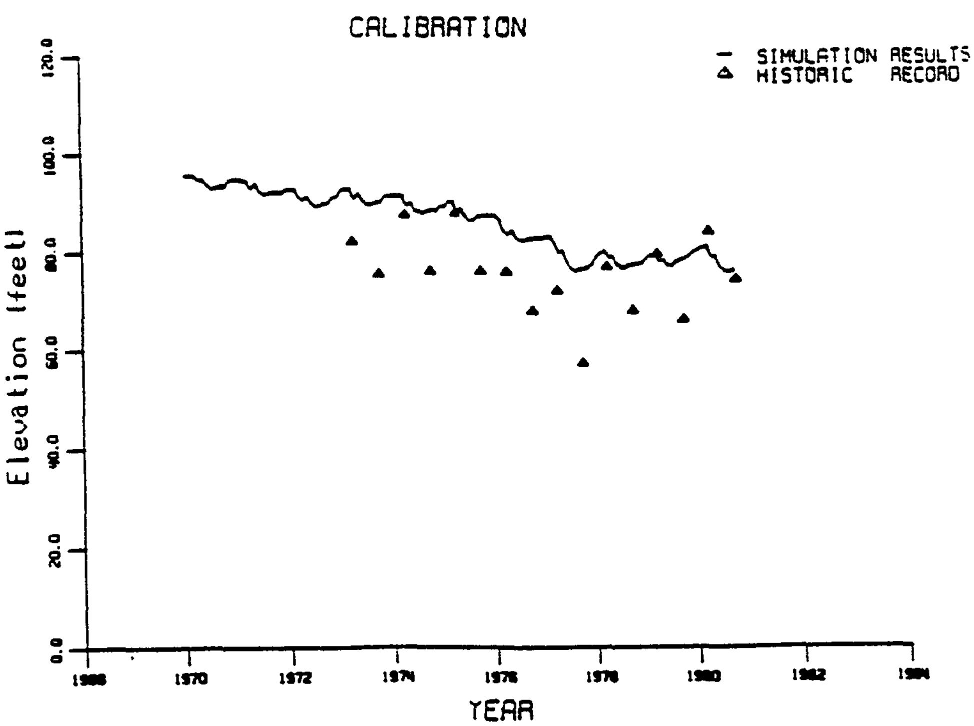


FIGURE 4.2(h)

WELL 3.2



C — 0 3 8 4 4 9

FIGURE 4.2(i)

WELL 4.1

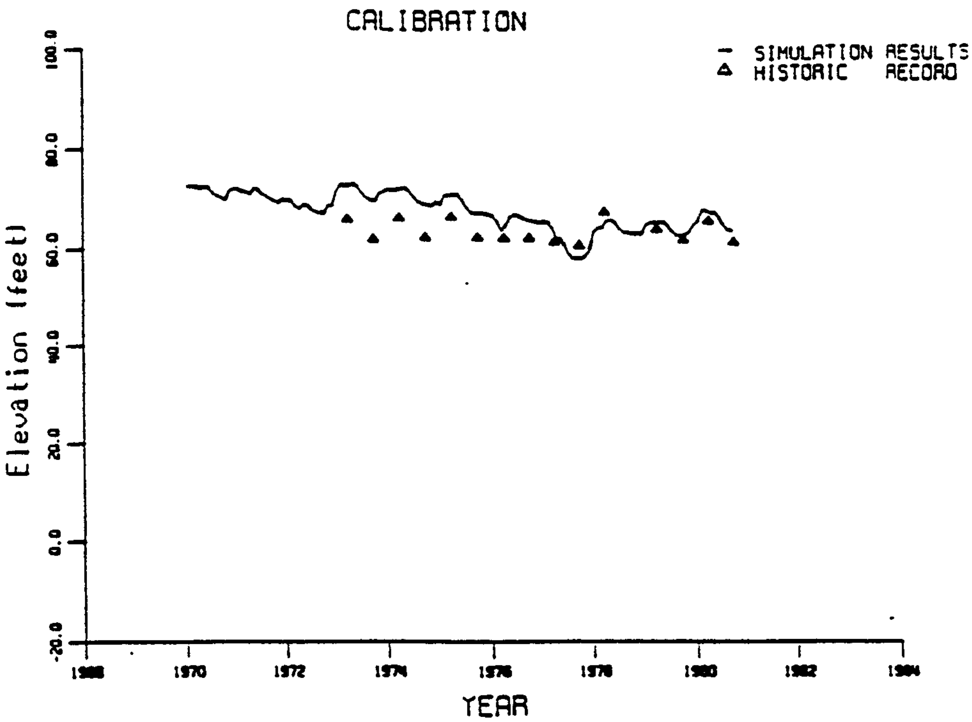


FIGURE 4.2(j)

WELL 4.2

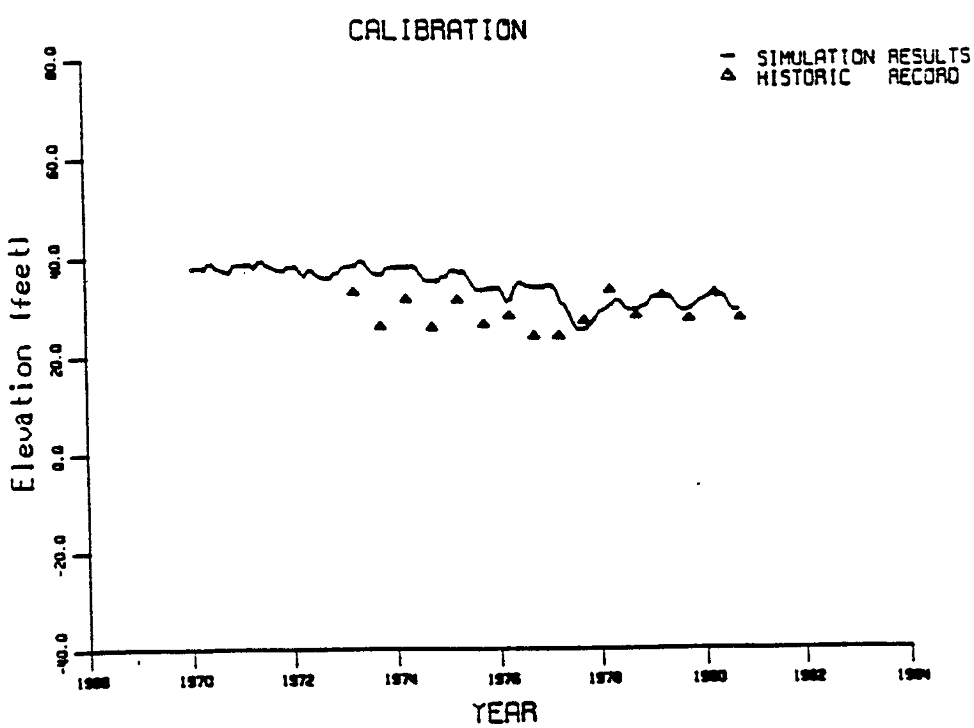


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FIGURE 4.2(k)

WELL 5.1

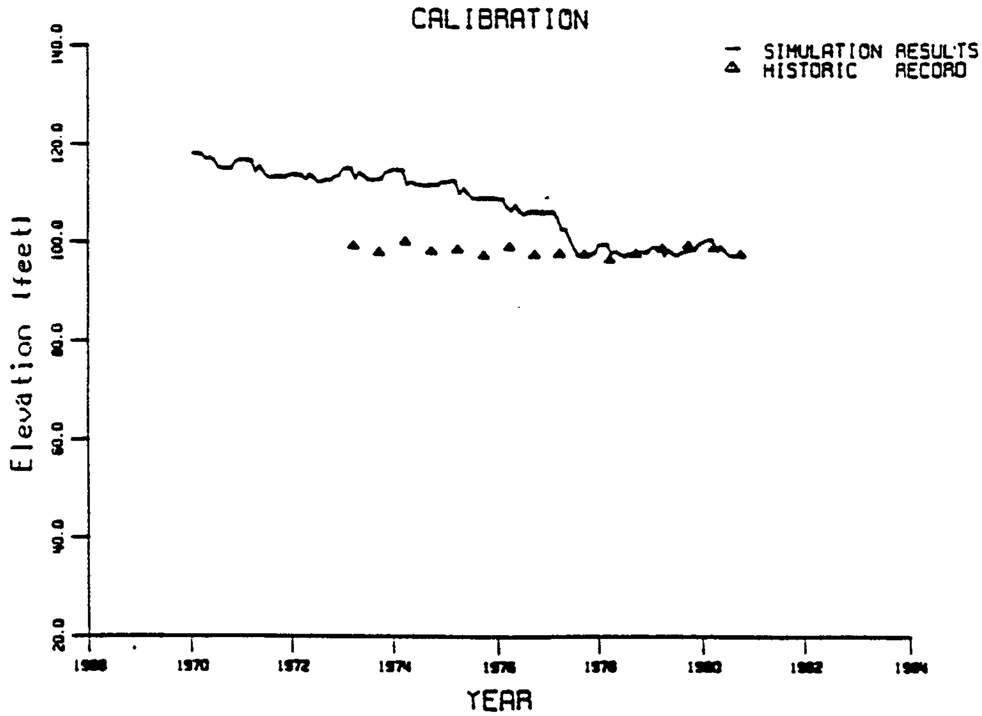


FIGURE 4.2(l)

WELL 5.2

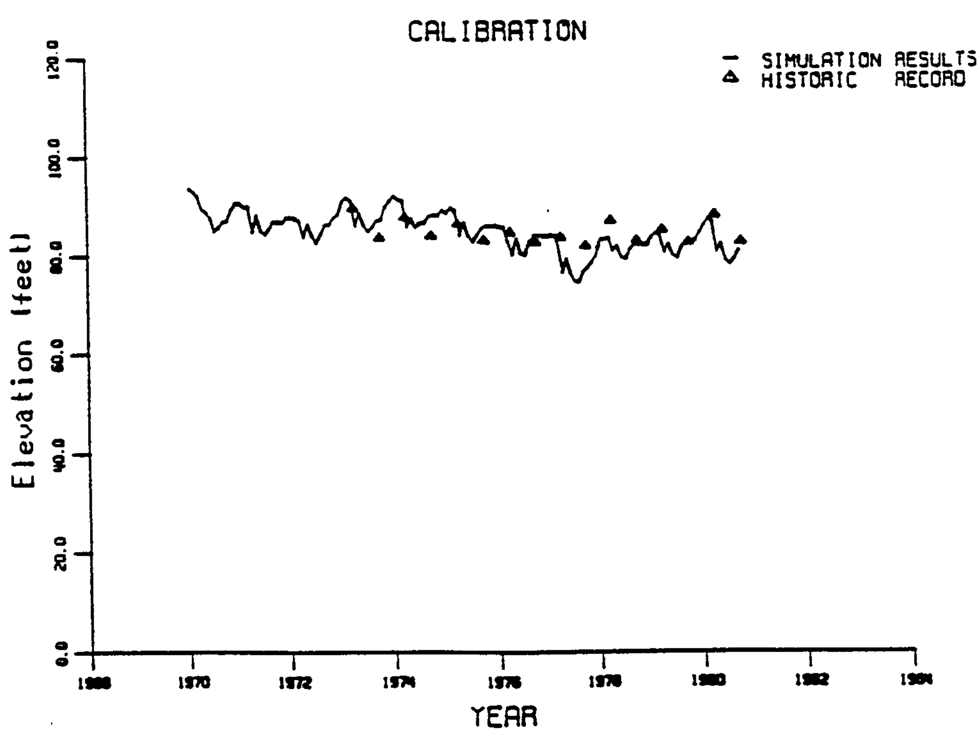


FIGURE 4.2(m)

WELL 5.3

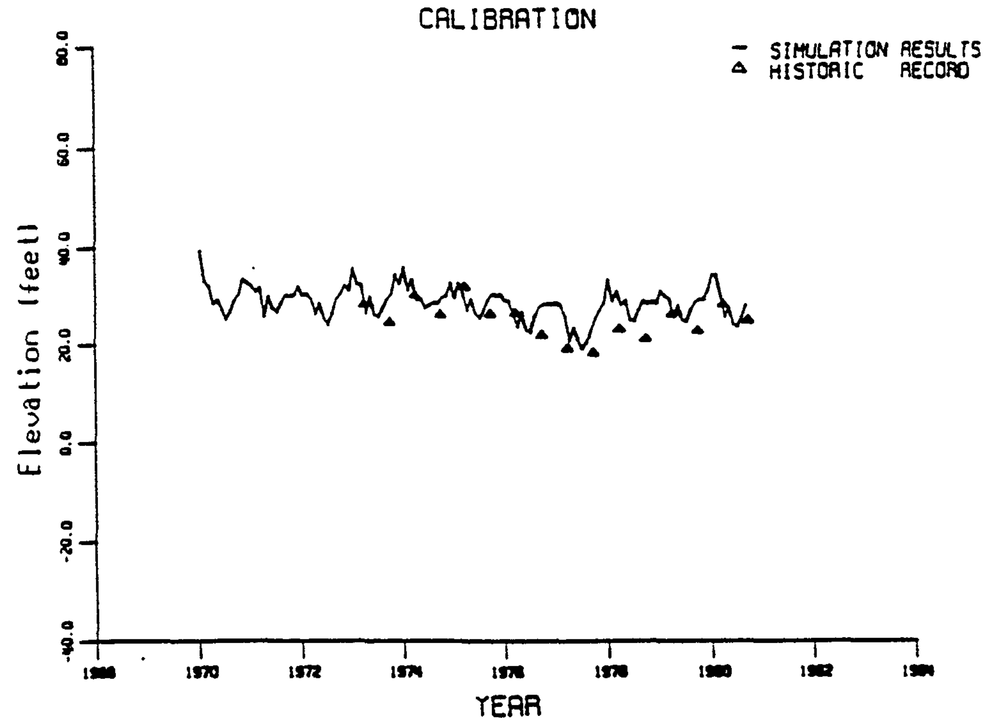
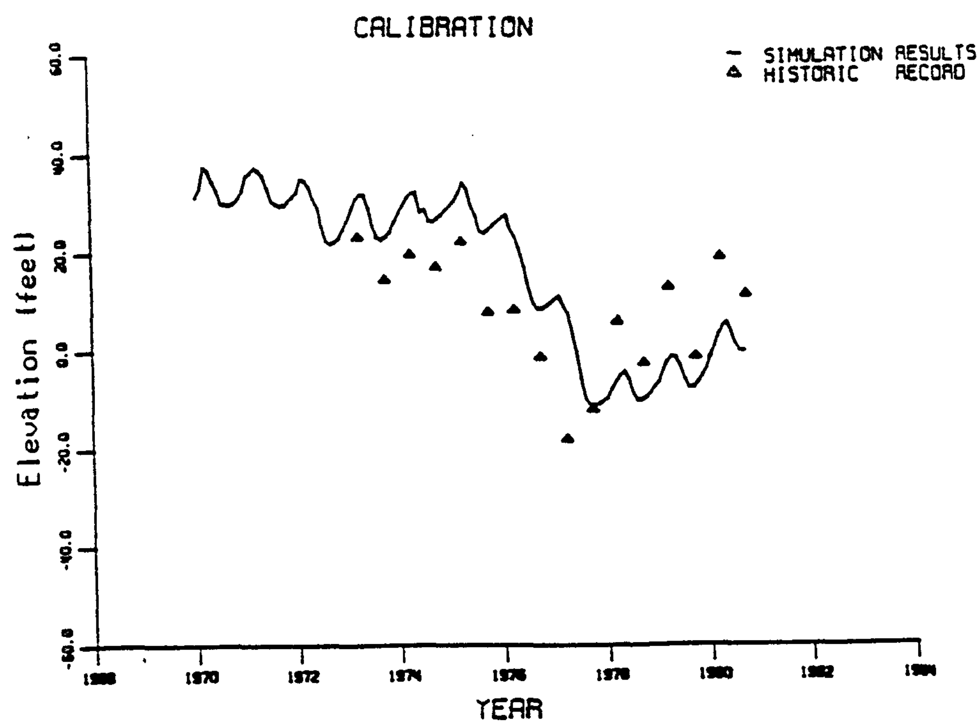


FIGURE 4.2(n)

WELL 6.1



C —0 3 8 4 5 2

FIGURE 4.2(o)

WELL 6.2

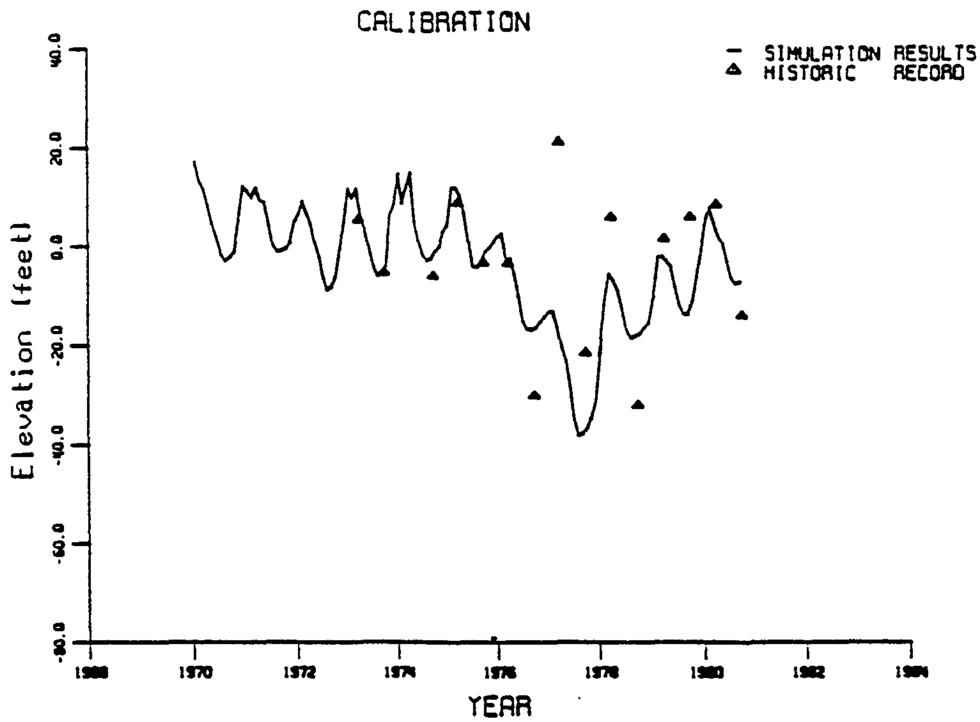
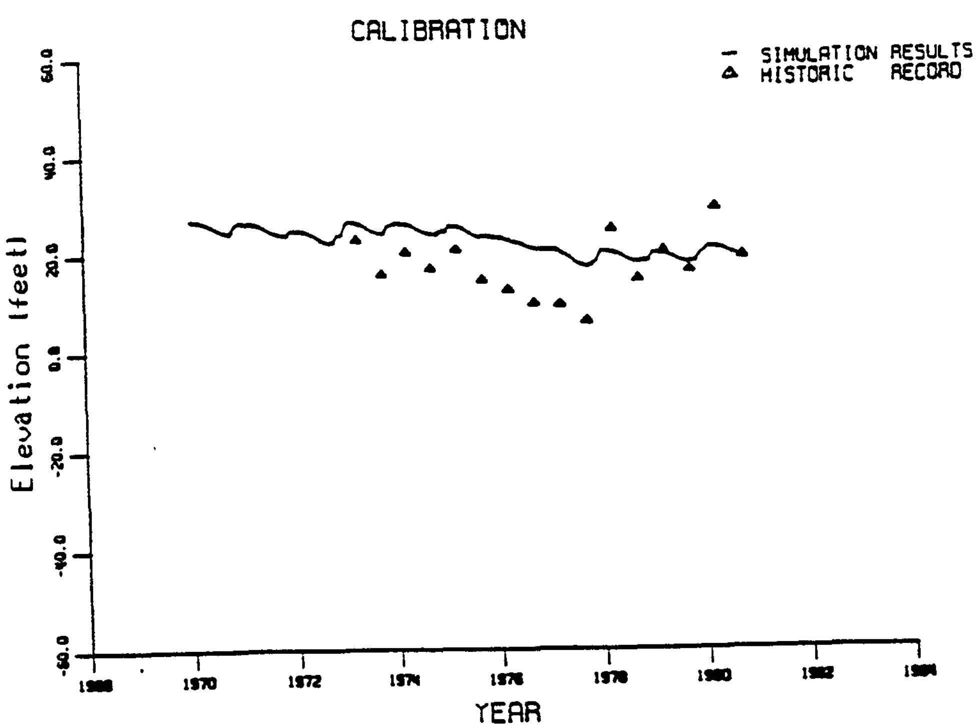


FIGURE 4.2(p)

WELL 6.3



C —0 3 8 4 5 3

FIGURE 4.2(q)

WELL 6.4

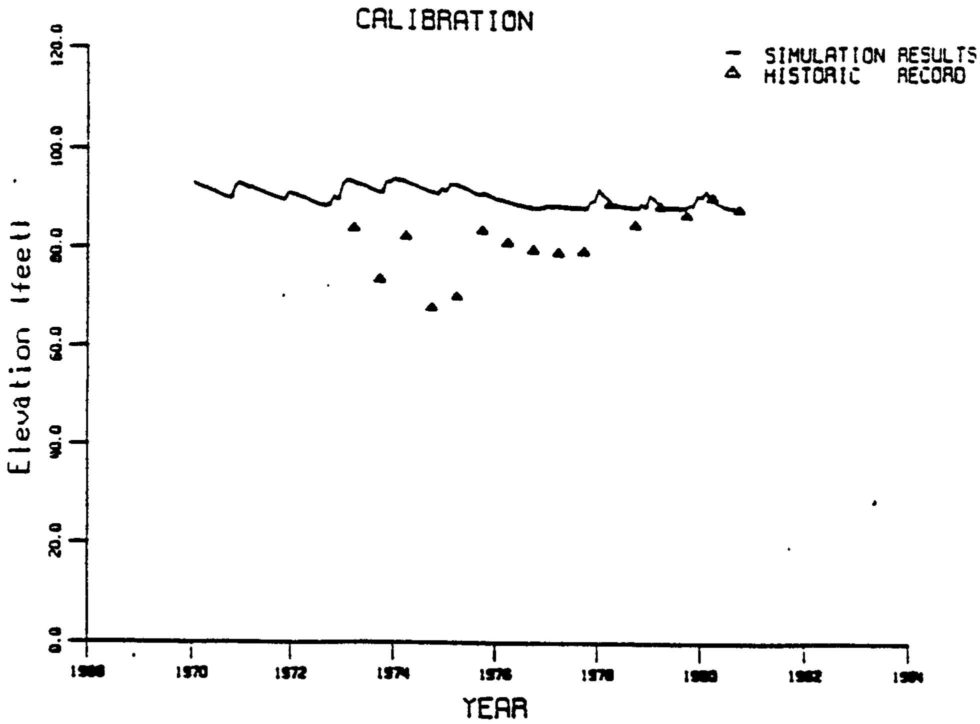


FIGURE 4.2(r)

WELL 7.1

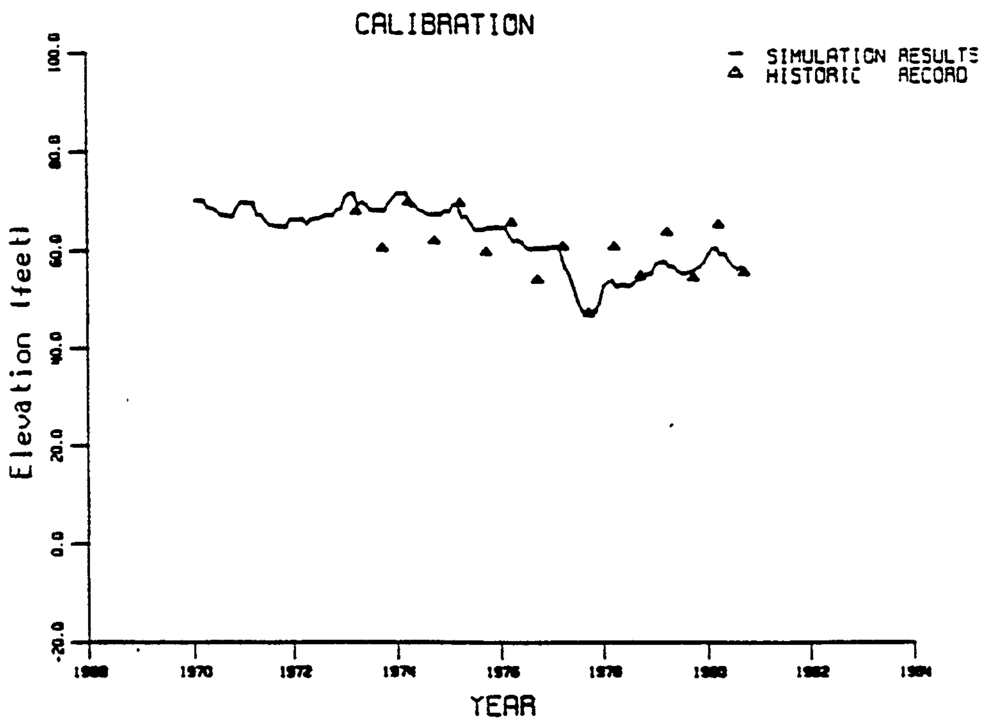


FIGURE 4.2(s)

WELL 7.2

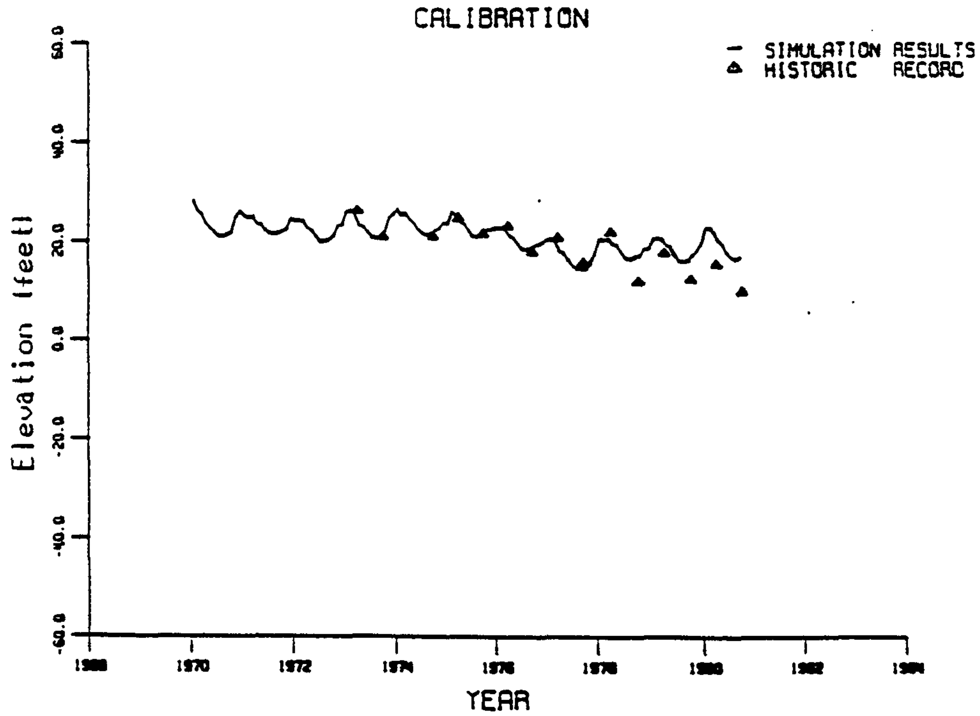


FIGURE 4.2(t)

WELL 8.1

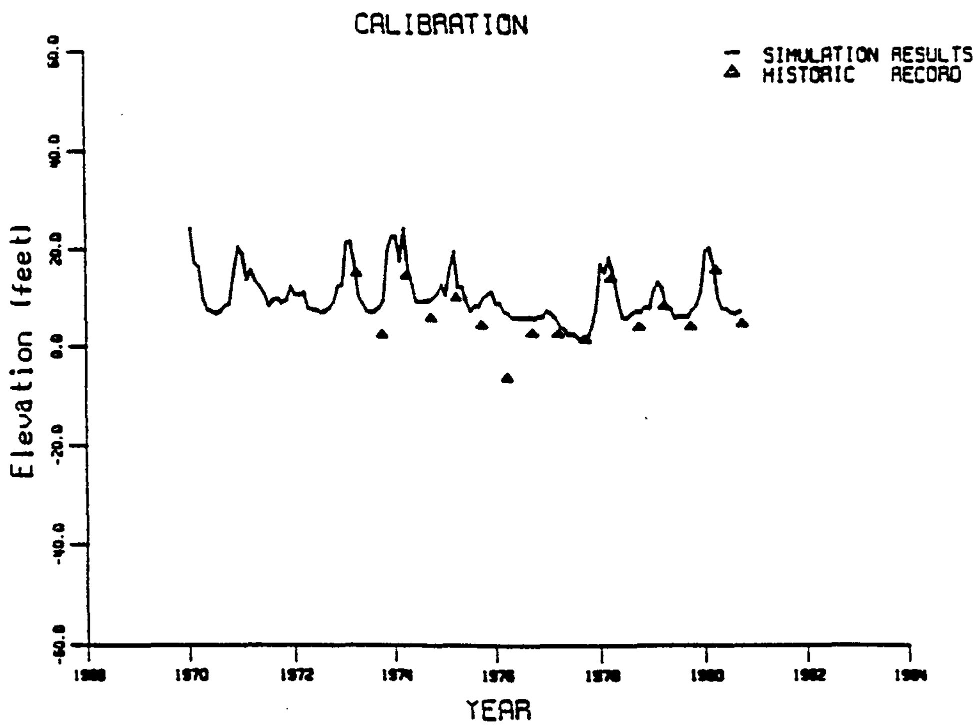


FIGURE 4.2(u)

WELL 8.2

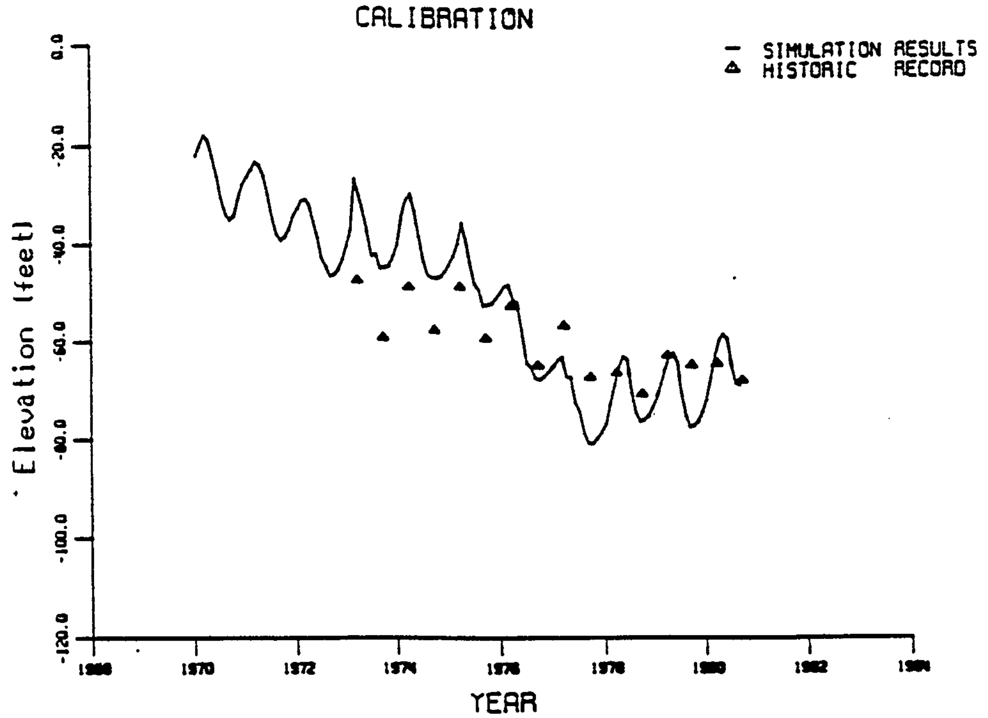


FIGURE 4.2(v)

WELL 8.3

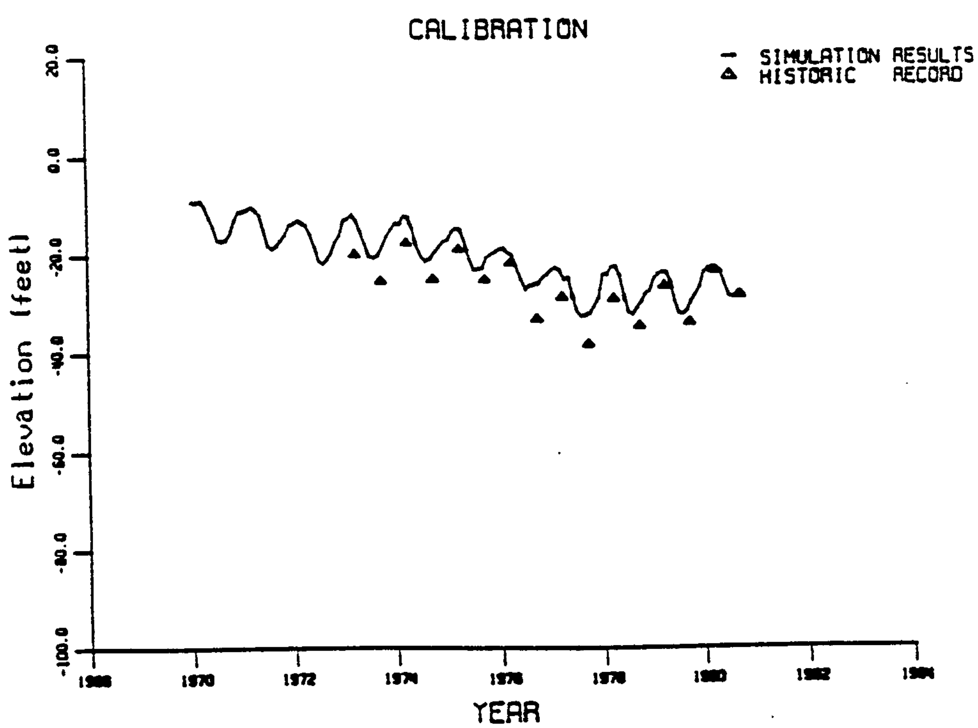


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FIGURE 4.2(w)
WELL 9.1

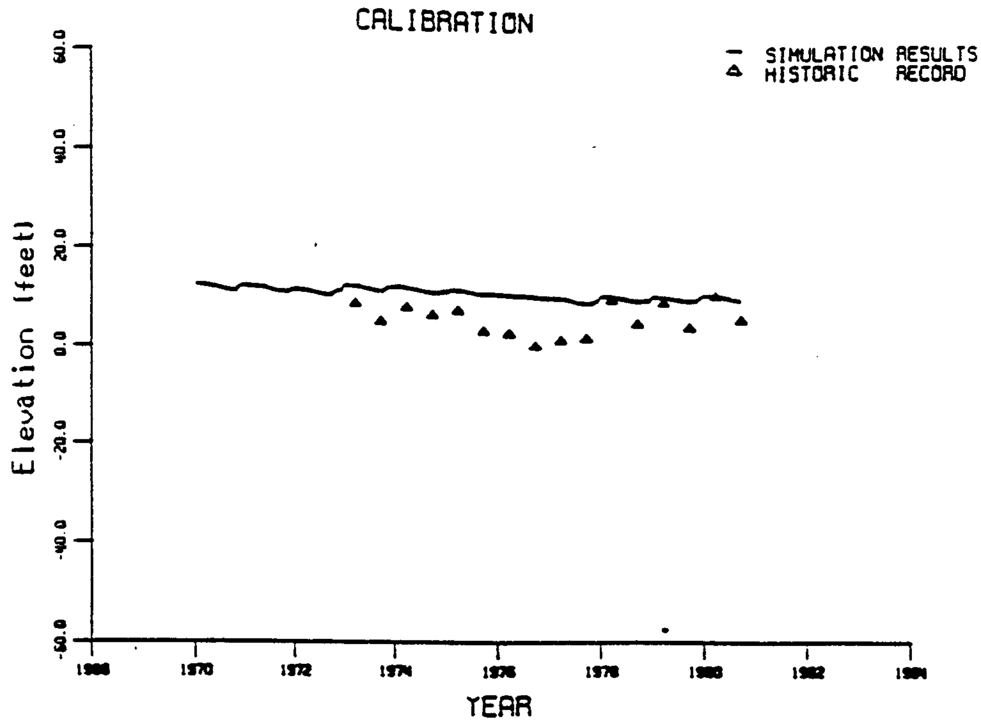

FIGURE 4.2(x)
WELL 10.1

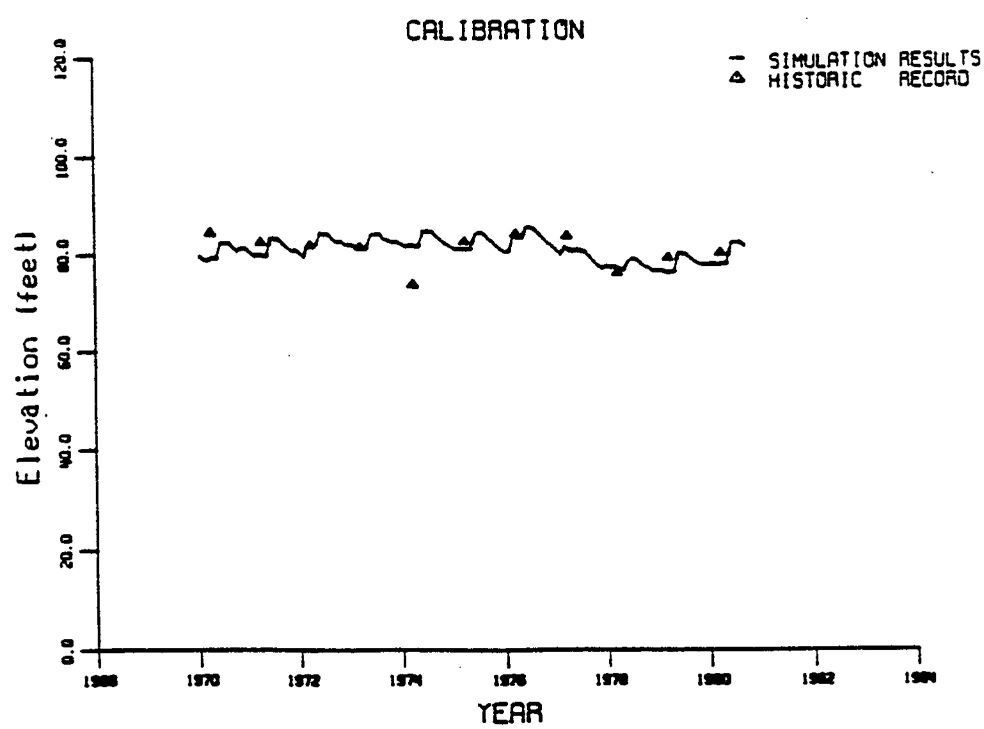

FIGURE 4.2(y)

WELL 10.2

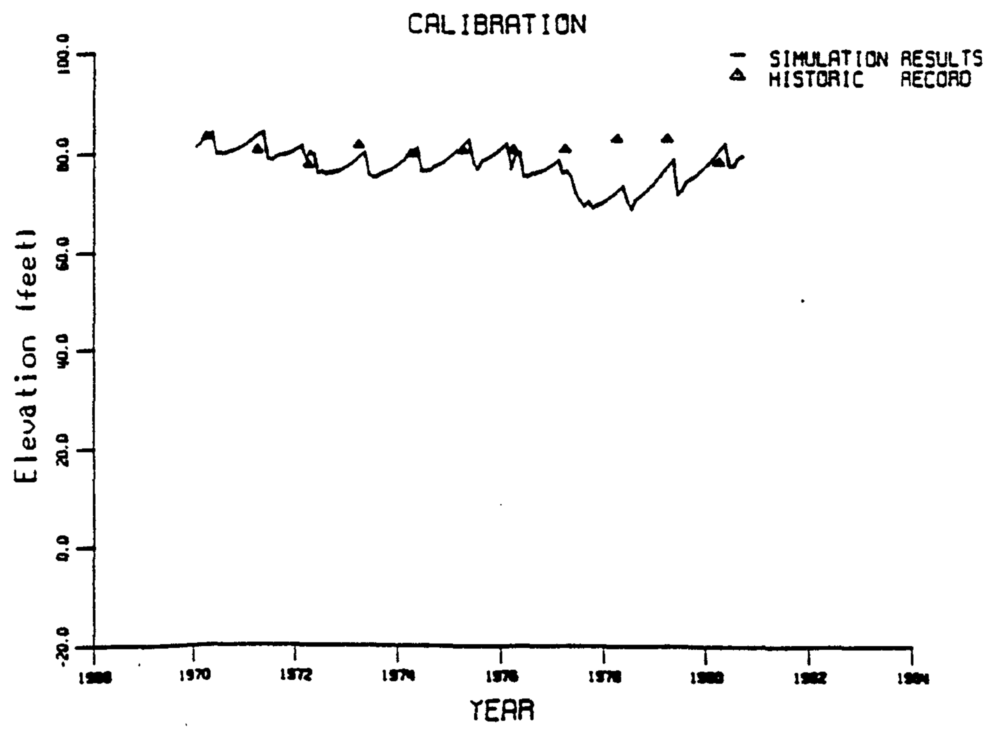

FIGURE 4.2(z)

WELL 11.1

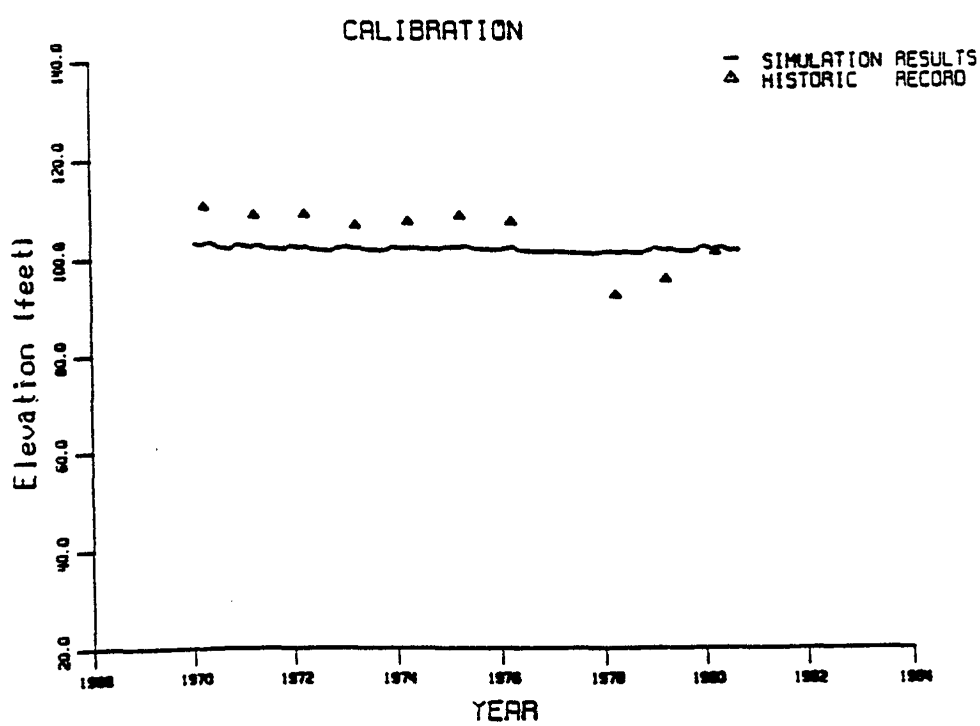

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FIGURE 4.2(aa)

WELL 11.2

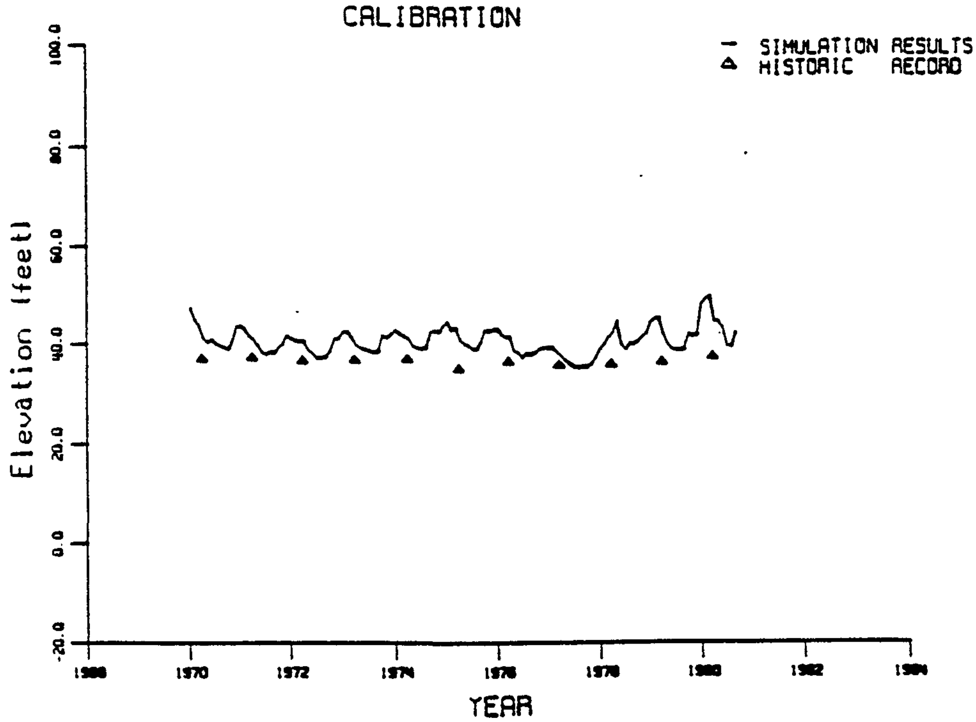

FIGURE 4.2(ab)

WELL 11.3

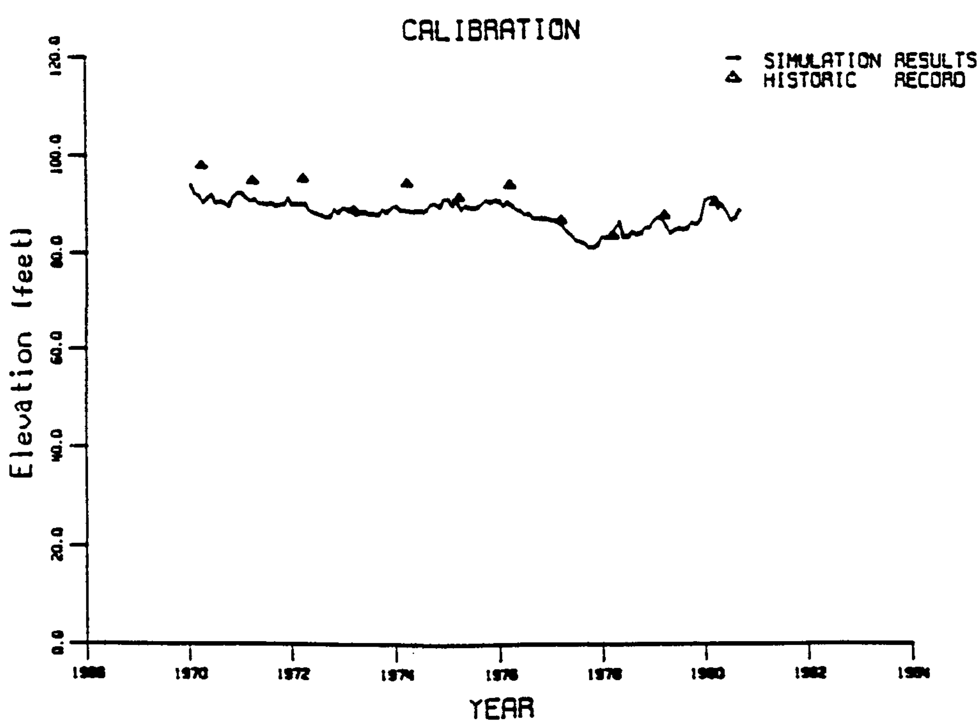

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FIGURE 4.2(ac)

WELL 12.1

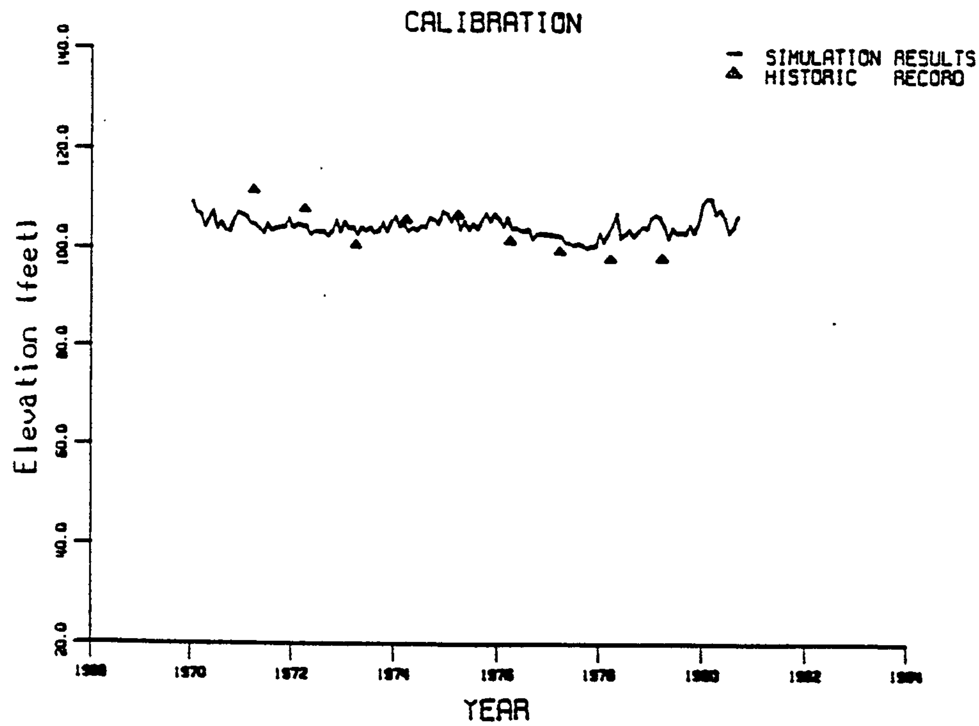

FIGURE 4.2(ad)

WELL 12.2

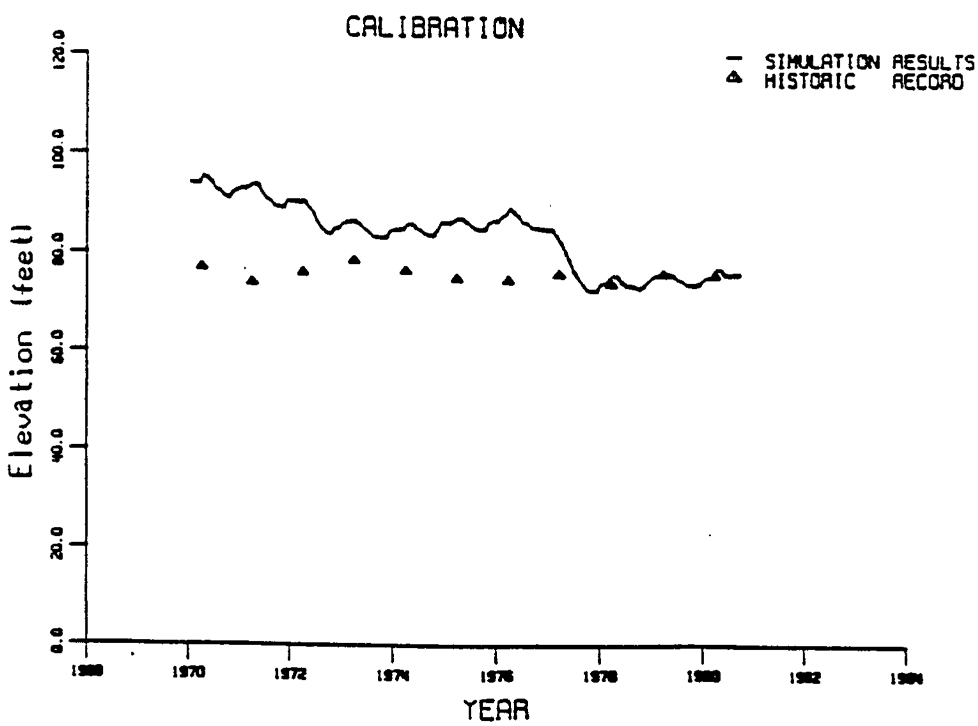

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FIGURE 4.2(ae)

WELL 13.1

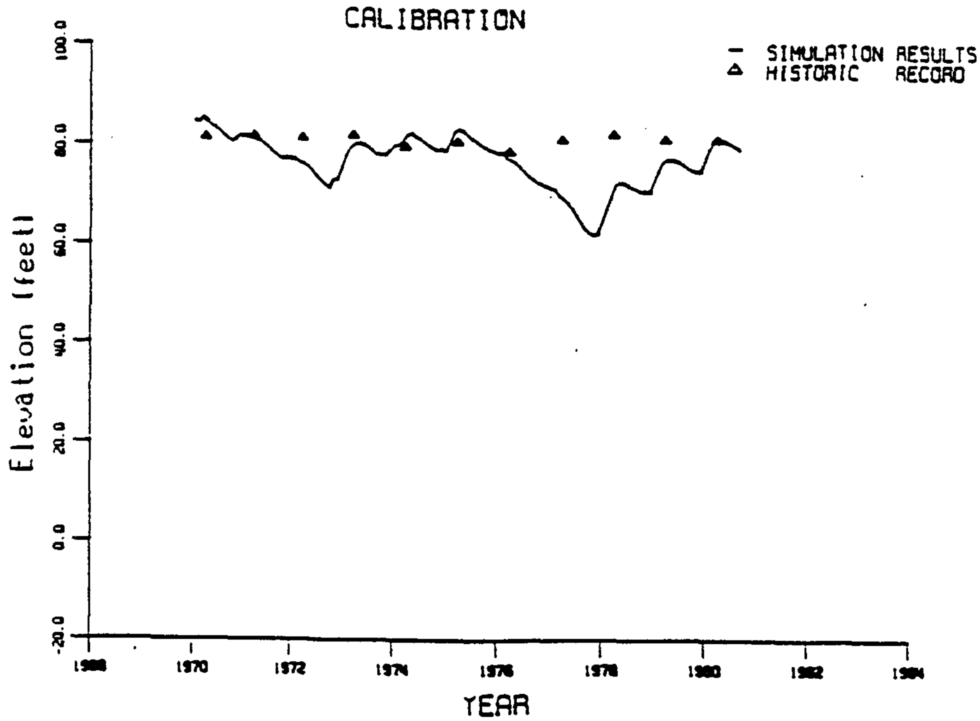

FIGURE 4.2(af)

WELL 13.2

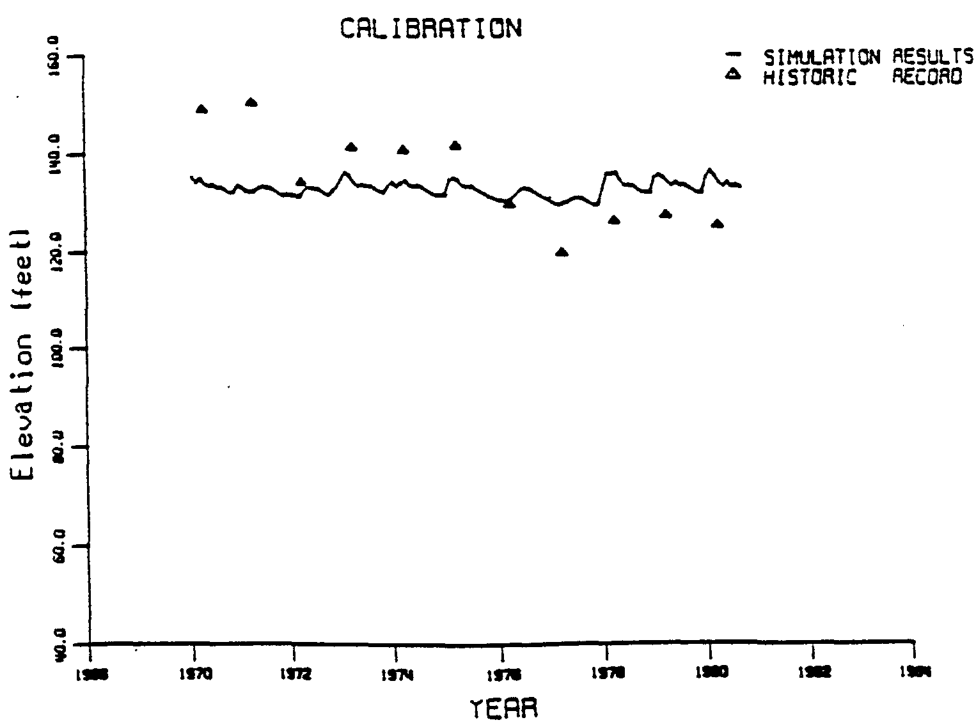

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FIGURE 4.2(ag)

WELL 13.3

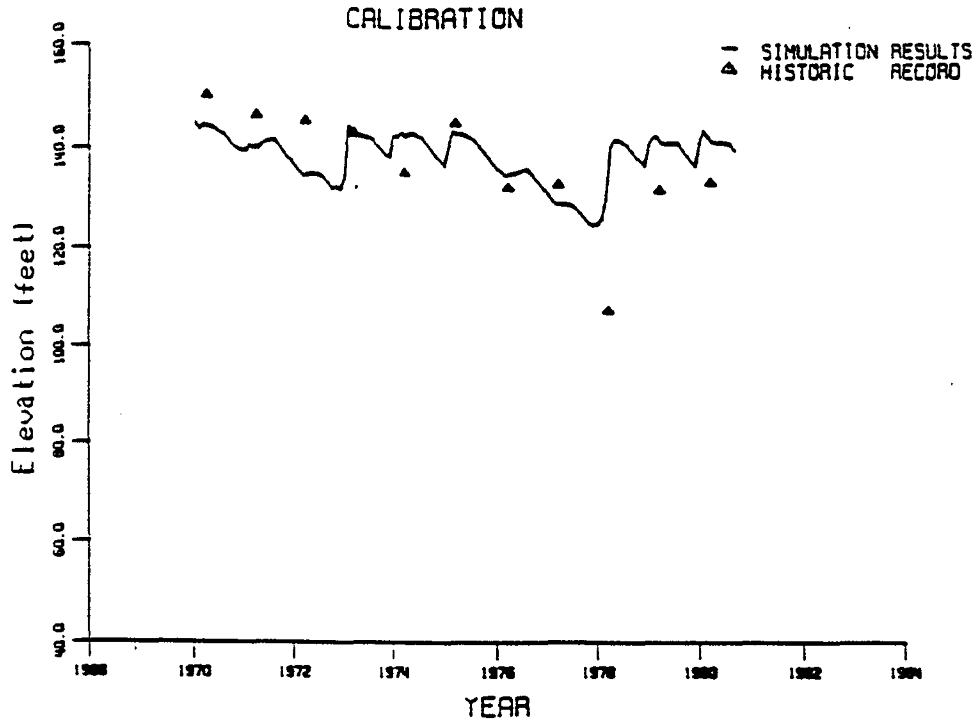

FIGURE 4.2(ah)

WELL 13.4

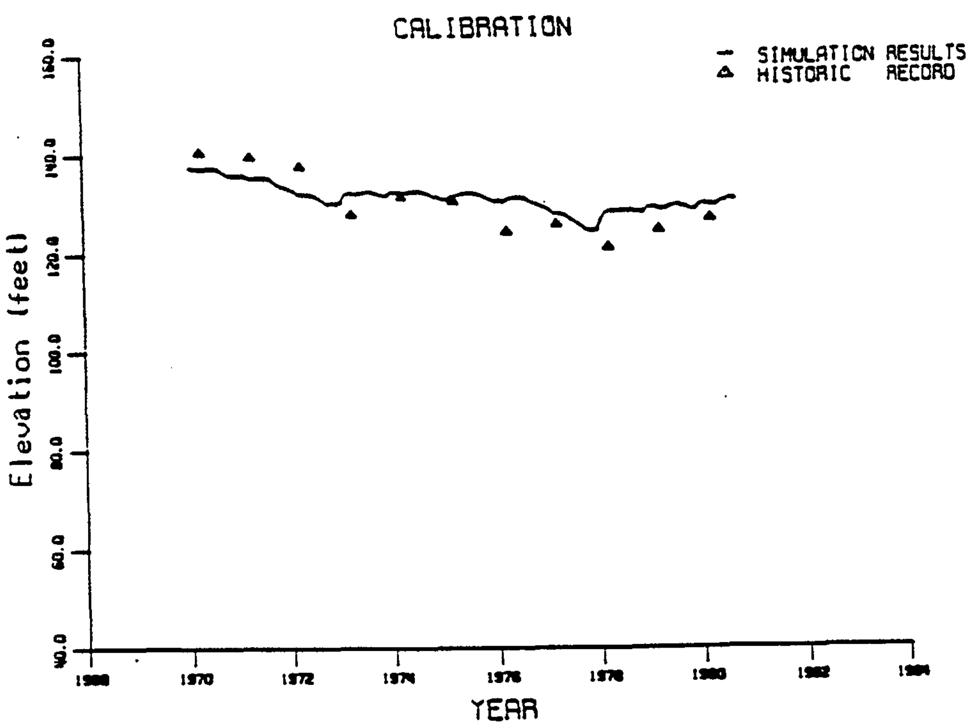

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FIGURE 4.2(ai)

WELL 14.1

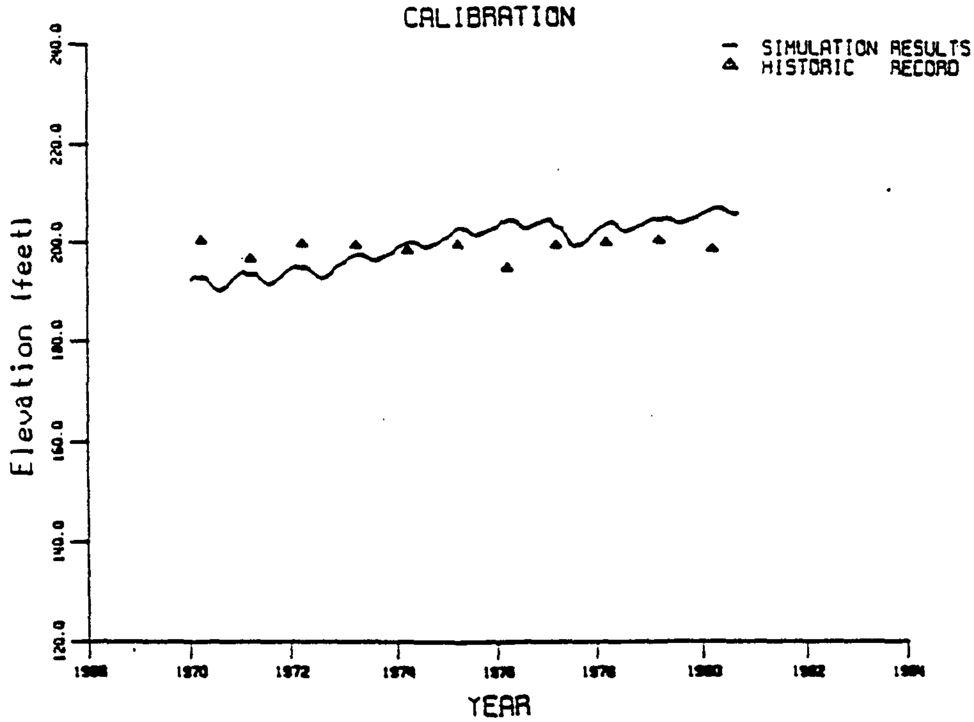


FIGURE 4.2(aj)

WELL 15.1

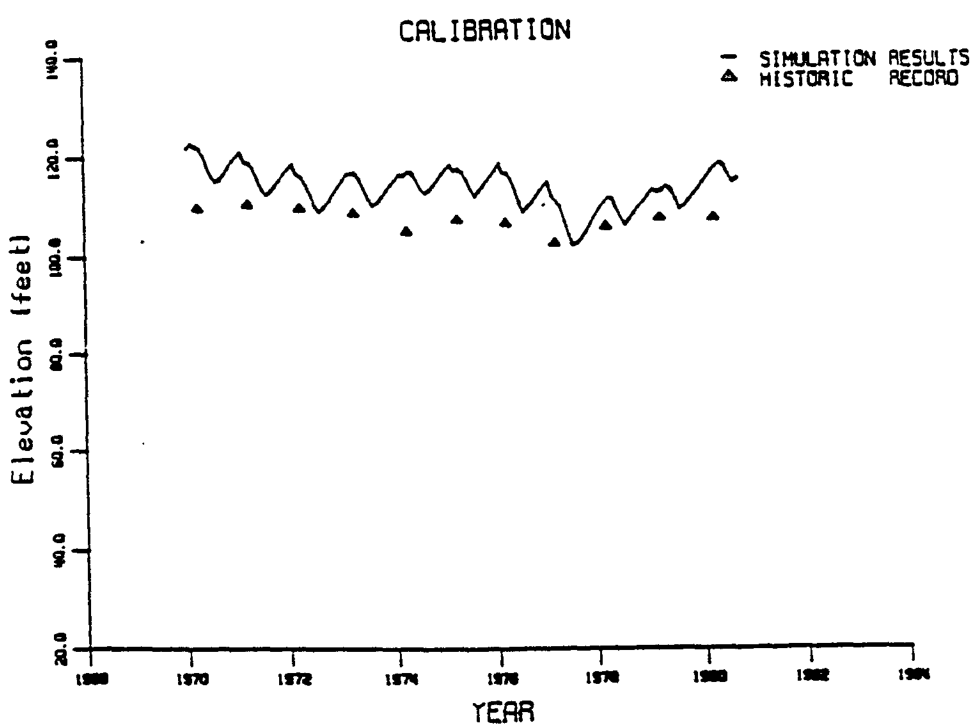


FIGURE 4.2(ak)
WELL 16.1

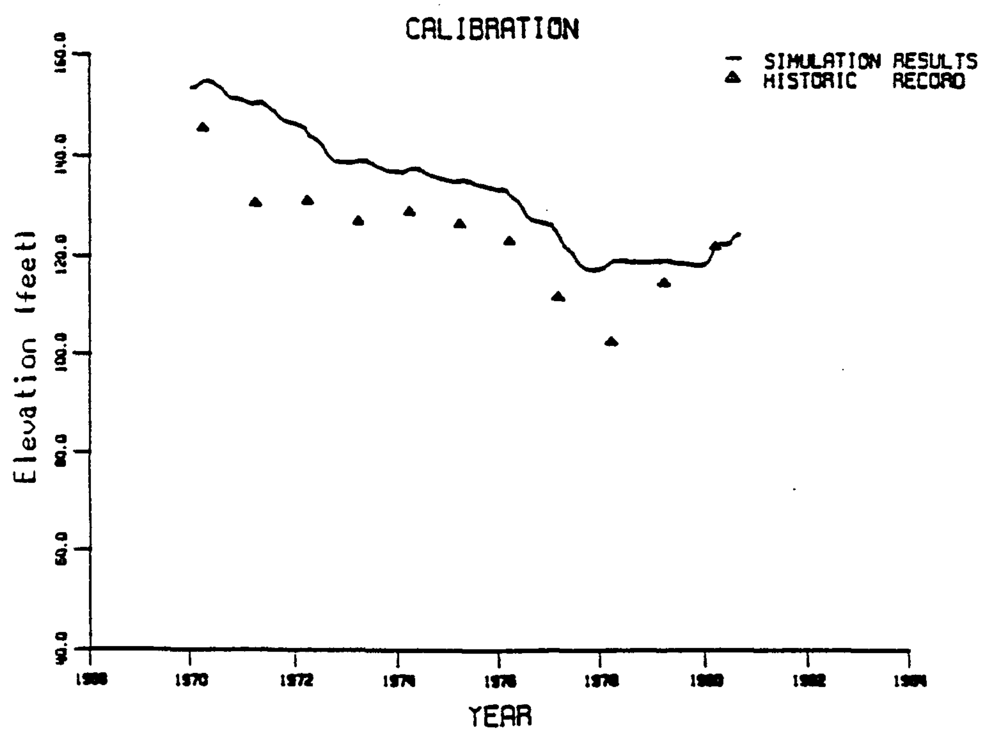


FIGURE 4.2(al)
WELL 17.1

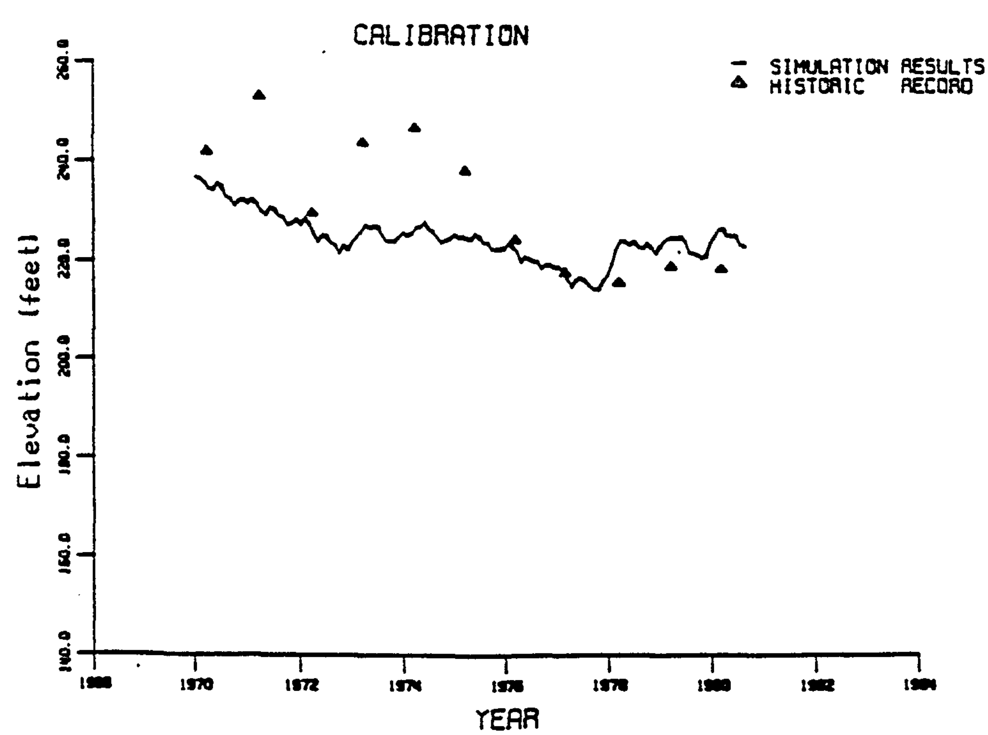


FIGURE 4.2(am)

WELL 18.1

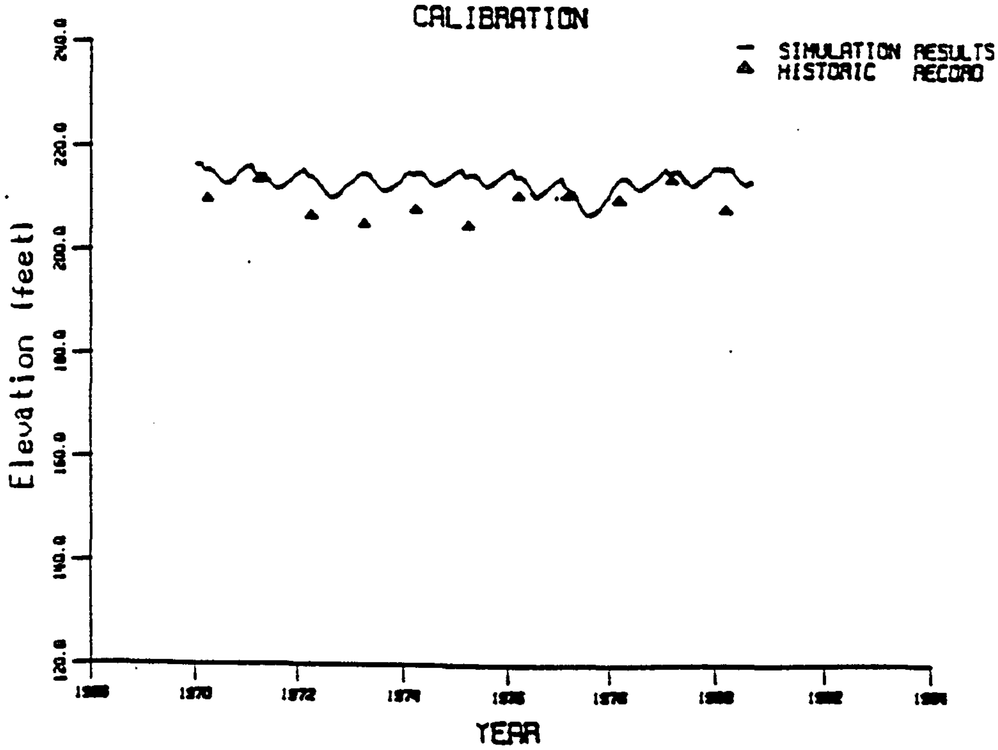


FIGURE 4.2(an)

WELL 18.2

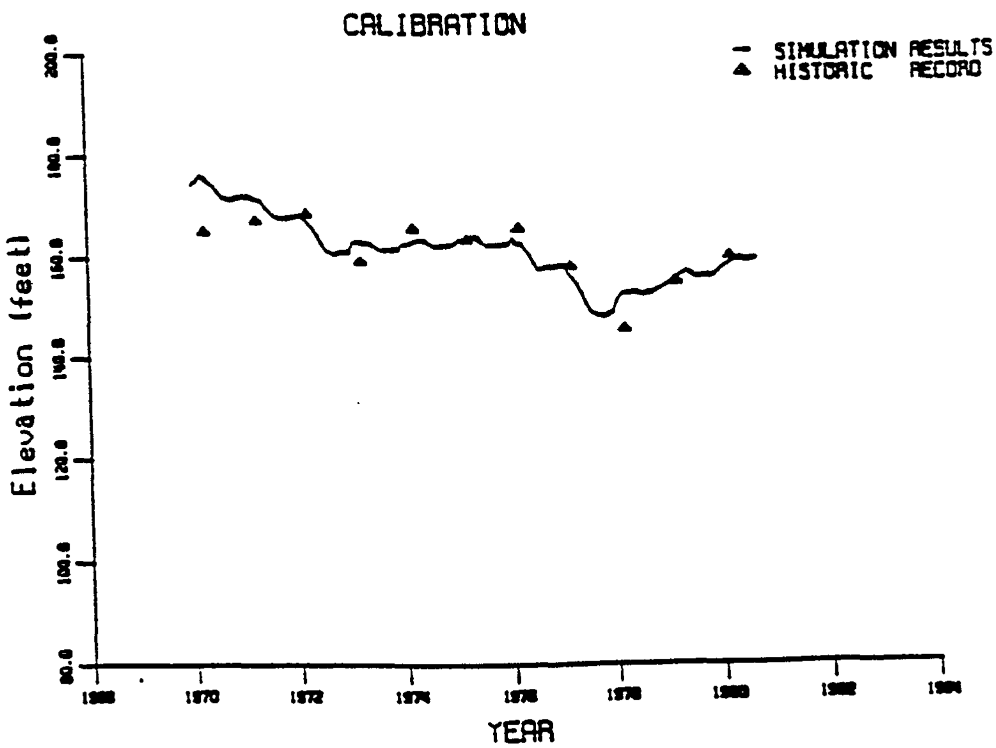


FIGURE 4.2(ao)

WELL 19.1

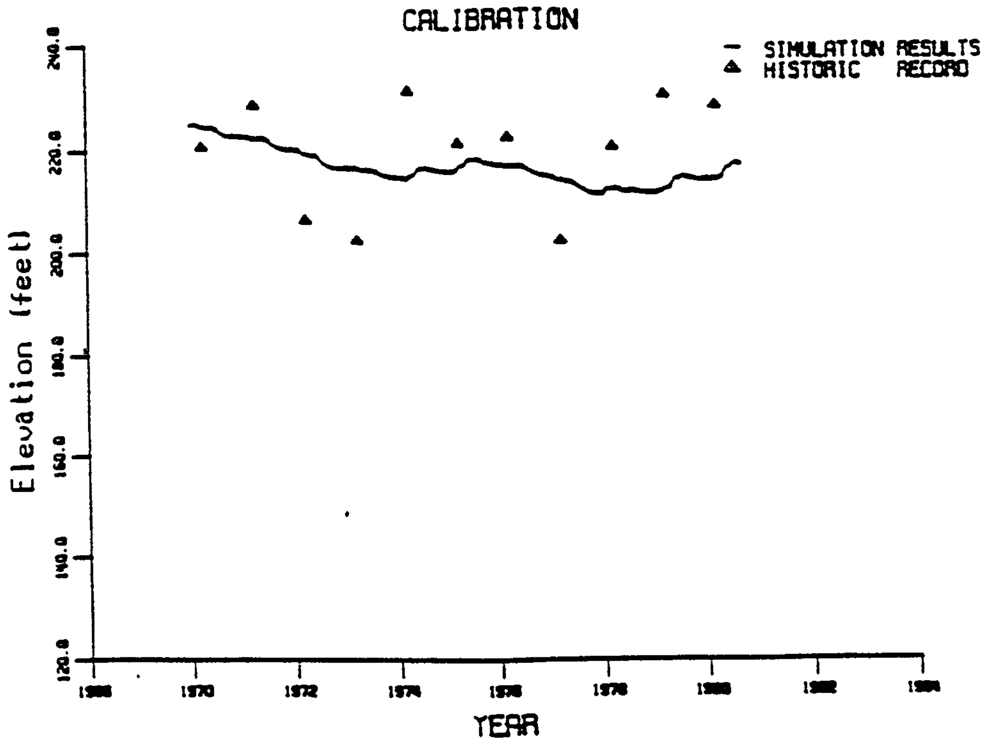


FIGURE 4.2(ap)

WELL 21.1

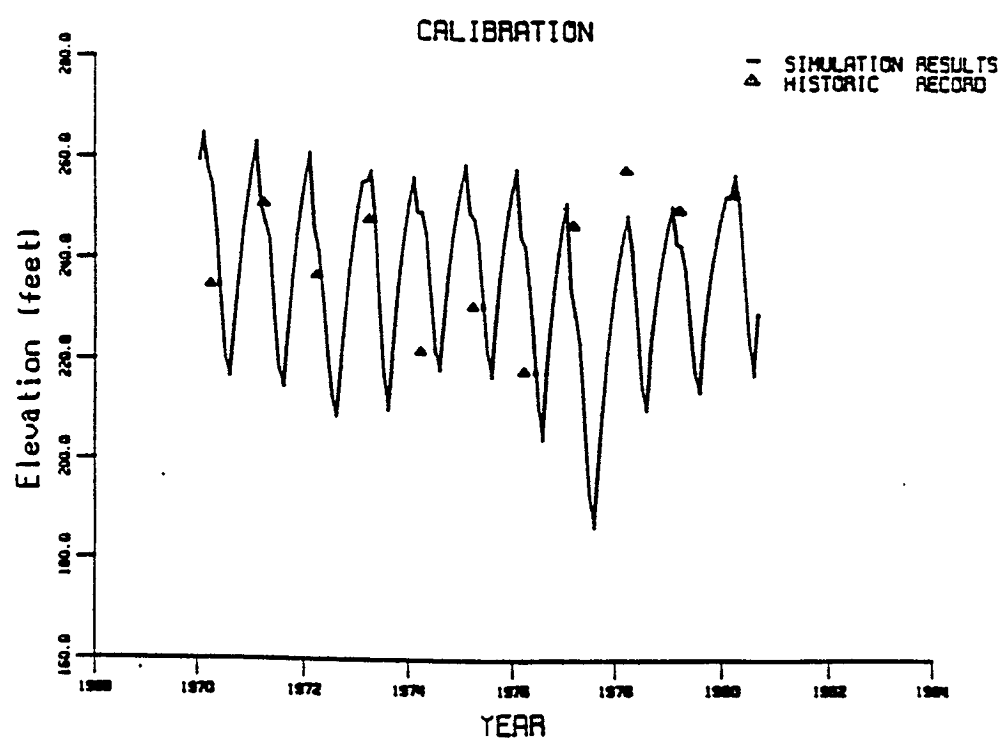
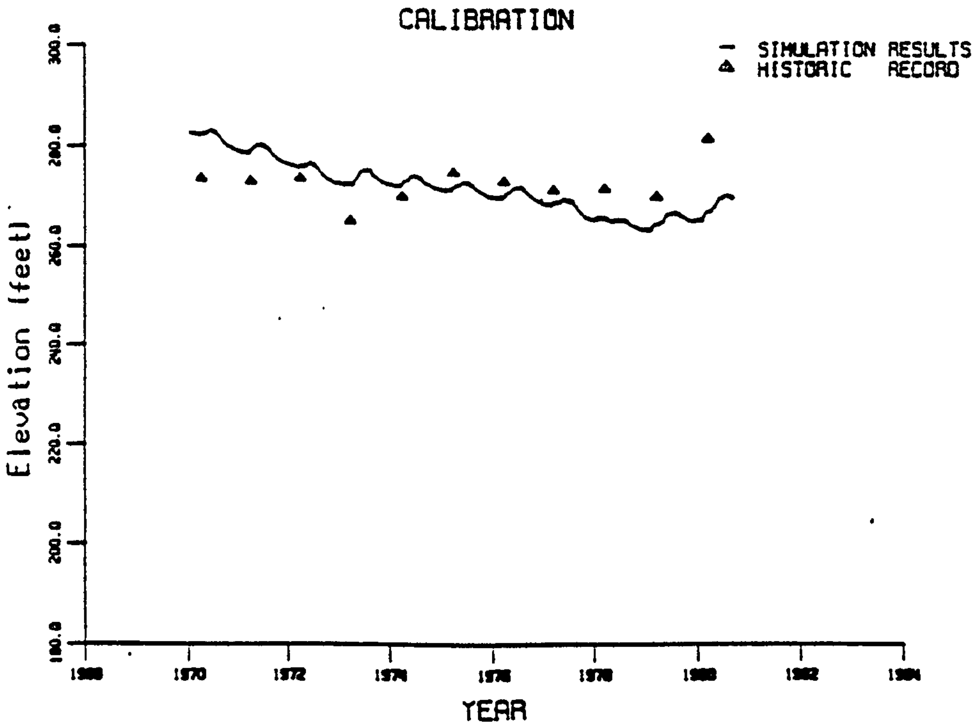


FIGURE 4.2(aq)

WELL 21.2



made hydrologic factors occurring on a small scale. In addition, the time step used in the simulation is one month. Consequently, it should be expected that the model only predicts hydrologic consequences on a macro scale basis by replicating regional and historic trends. Certain discrepancies on a local scale should be expected.

Input Data Error: Input data used in the model represents the use of the best information available at this time. Where data was not available, it was estimated based on engineering judgement or inferred from other sources. One of the most critical sets of input data affecting the response of the groundwater tables in the study area is agricultural pumping. As discussed previously, this data is based on estimation. Many of the discrepancies between measured and simulated water levels occurred during the pumping periods which can be attributed to errors in the pumping estimates.

Measurement Error: It is probable that some observed water levels are influenced by pumping and do not represent regional water level conditions, or include large measurement errors.

Figure 4.3 shows a summary of the error analysis. Approximately 82 percent of simulated water levels are within 10 feet of observed water levels.

Figures 4.4(a) and 4.4(h) present a comparison of simulated and measured streamflows. The results again indicate that the model is capable of reliably simulating the hydrologic conditions in the Valley.

4.4 SENSITIVITY ANALYSIS

Analyses were performed to assess the sensitivity of model results to major parameters or variables used in the simulation. The performance criteria used are

1. $$\frac{1}{N}\sum_{i}^{N}(h_i^{Cal} - h_i)$$

2. Percent change in average annual Delta Flow.

In the above criteria, N is a total number of model nodes in all three layers (4179 nodes), and h_i^{Cal} and h_i respectively represent the calibrated water levels and water levels resulting from perturbed parameters for each node i. The Delta inflows are taken as a combination of flows from Sacramento River, Yolo Bypass, San Joaquin River, and Eastern Side Stream (outflows from DSA 65, DSA 70, DSA 49 and DSA 59, respectively).

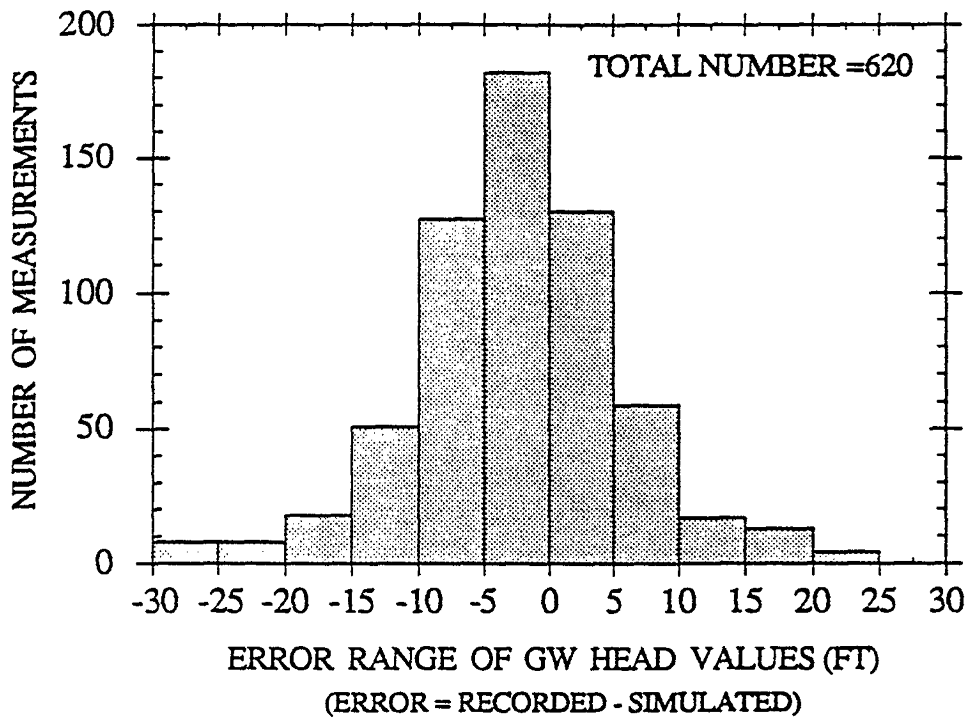


FIGURE 4.3
ACCURACY OF MODEL RESULTS

FIGURE 4.4(a)

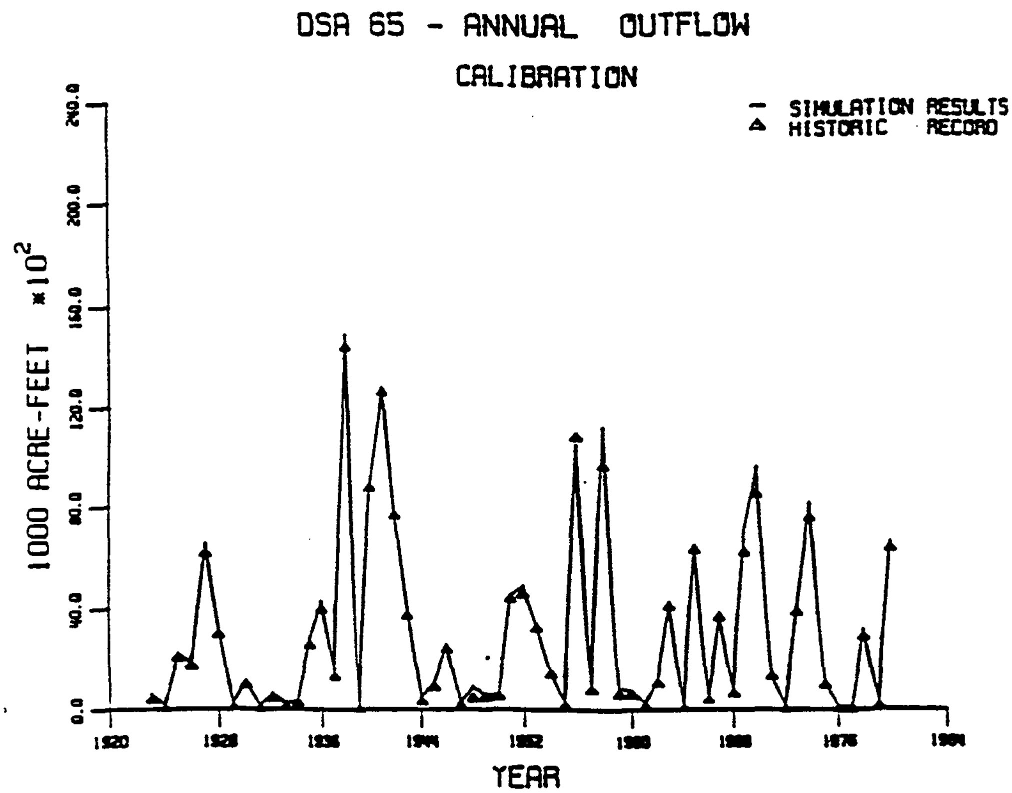


FIGURE 4.4(b)

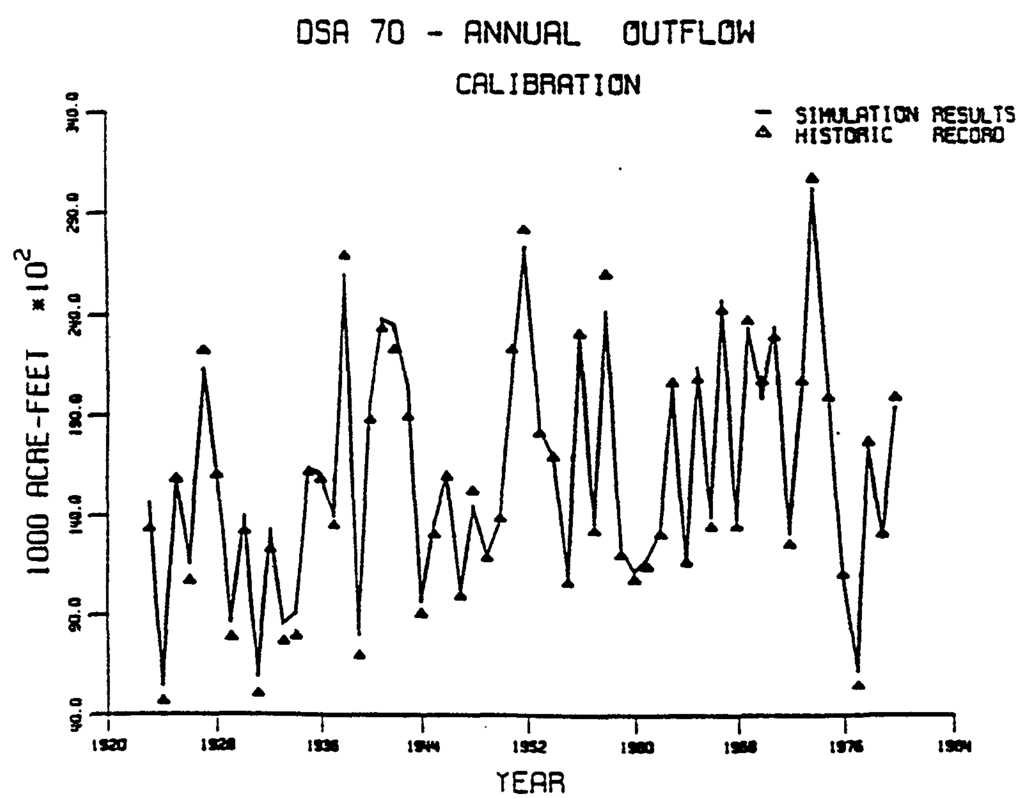


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FIGURE 4.4(c)

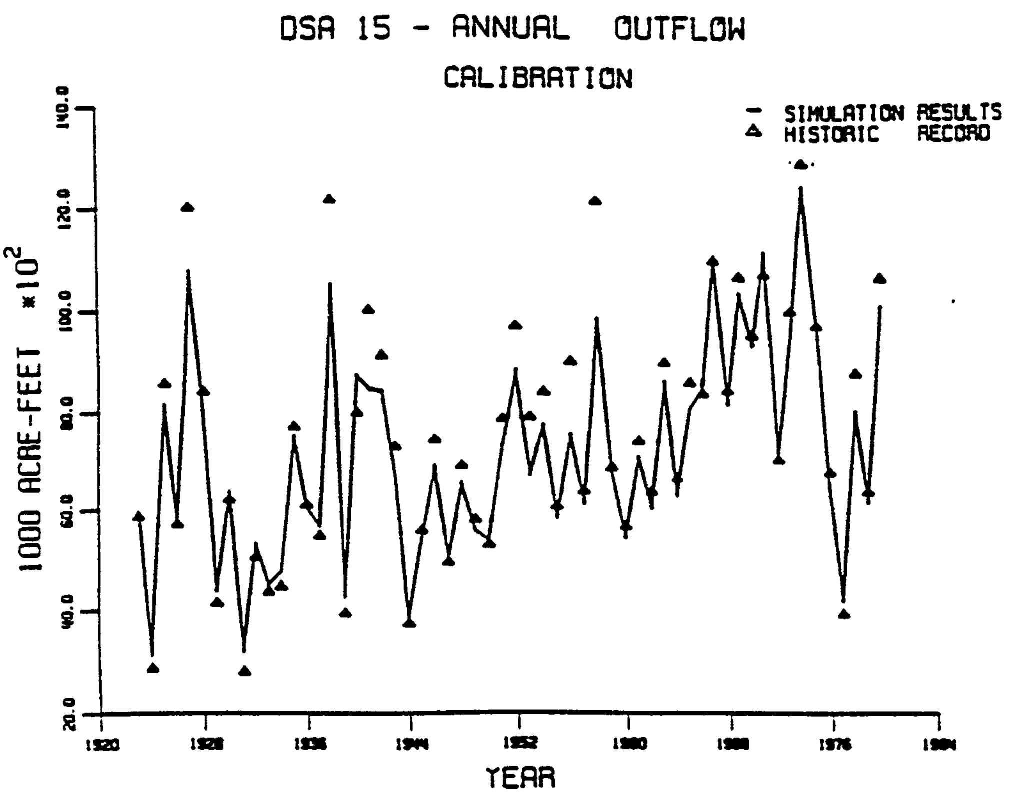
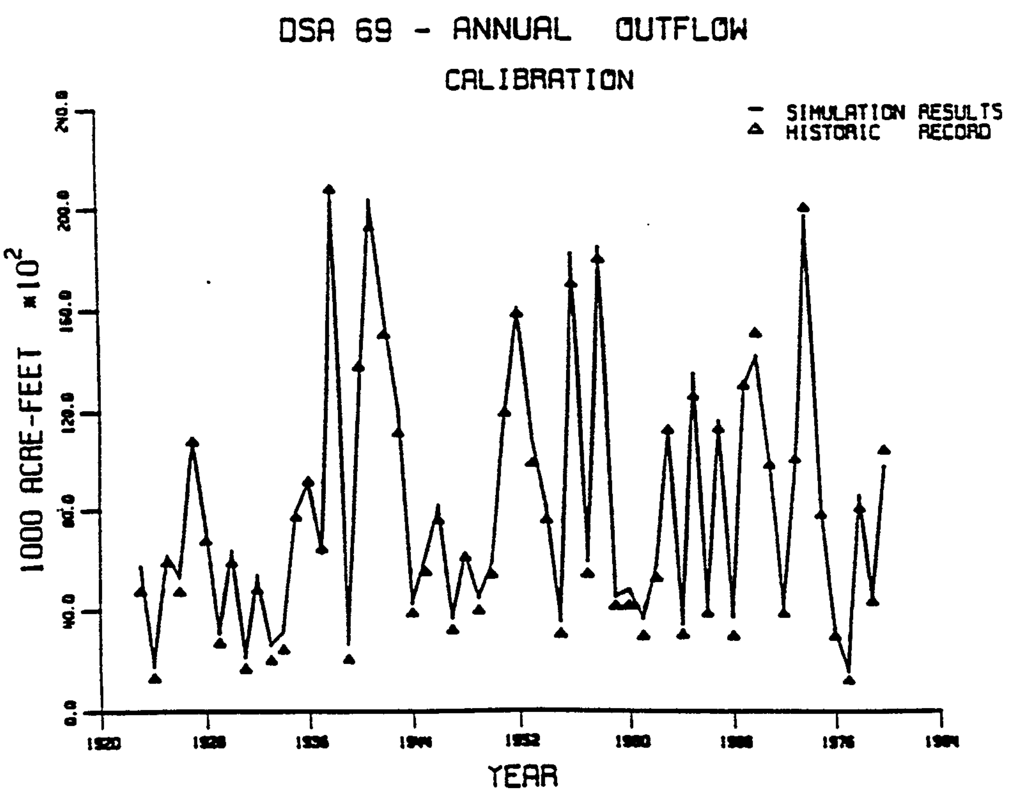


FIGURE 4.4(d)



C—038471

FIGURE 4.4(e)

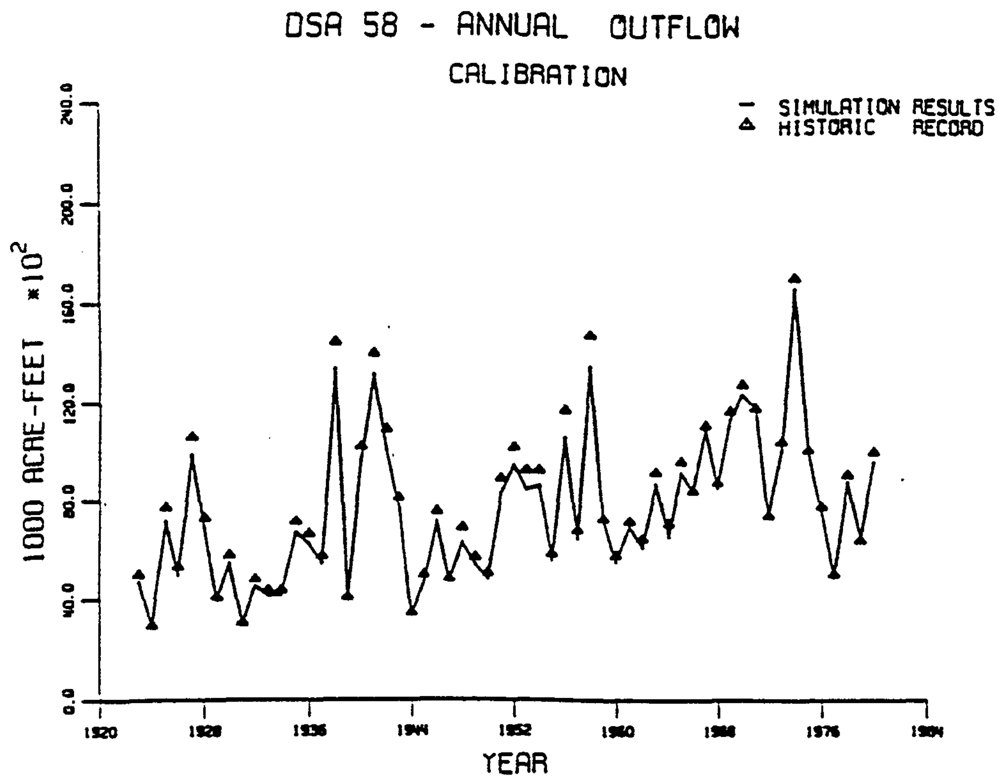
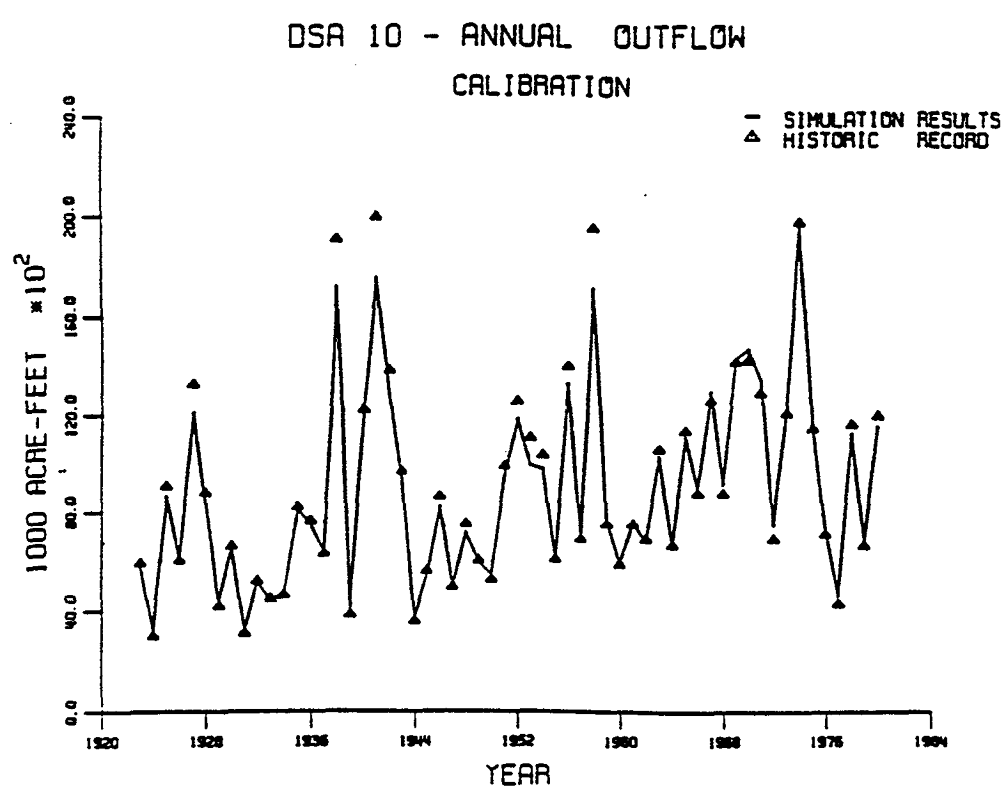


FIGURE 4.4(f)



C—038472

FIGURE 4.4(g)

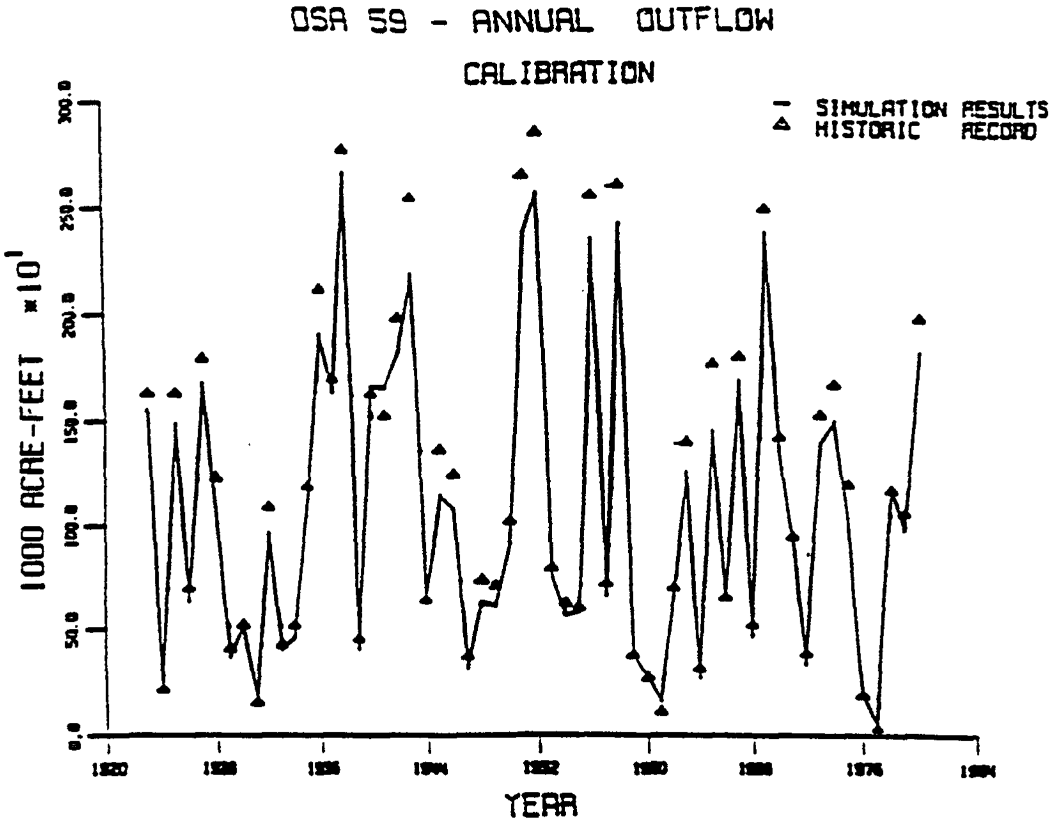
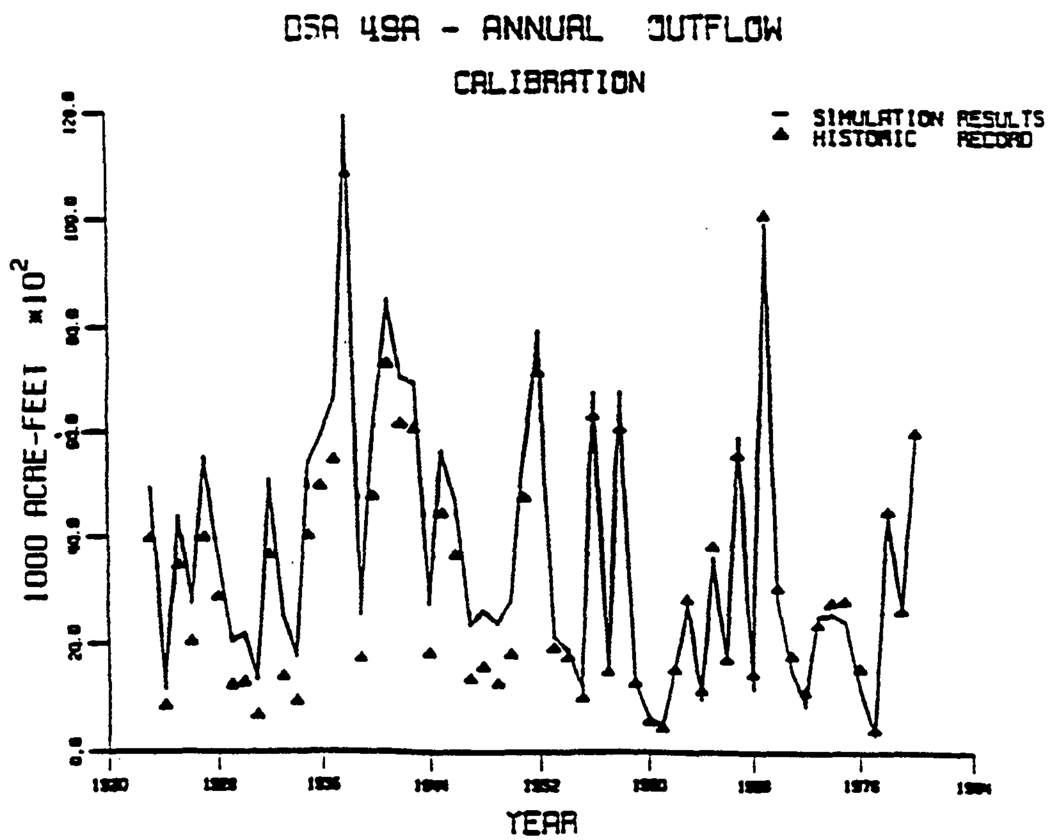


FIGURE 4.4 (h)



C-038473

For the sensitivity analysis, one of the parameters was selected and perturbed by a fixed percent and a model run was made for a period from 1960 to 1980. The results were then compared with the calibrated heads or Delta flows using the above criteria. The results are presented in Figures 4.5(a) through 4.5(k).

As can be seen from the figures, model results are the most sensitive to water budget variables such as rain, pumping and irrigation acreages. The model parameters are rather insignificant as compared to these variables on a regional basis. However, importance of these parameters should not be overlooked. Local variations of hydraulic conductivities or storage coefficients may have significant impacts on local water tables.

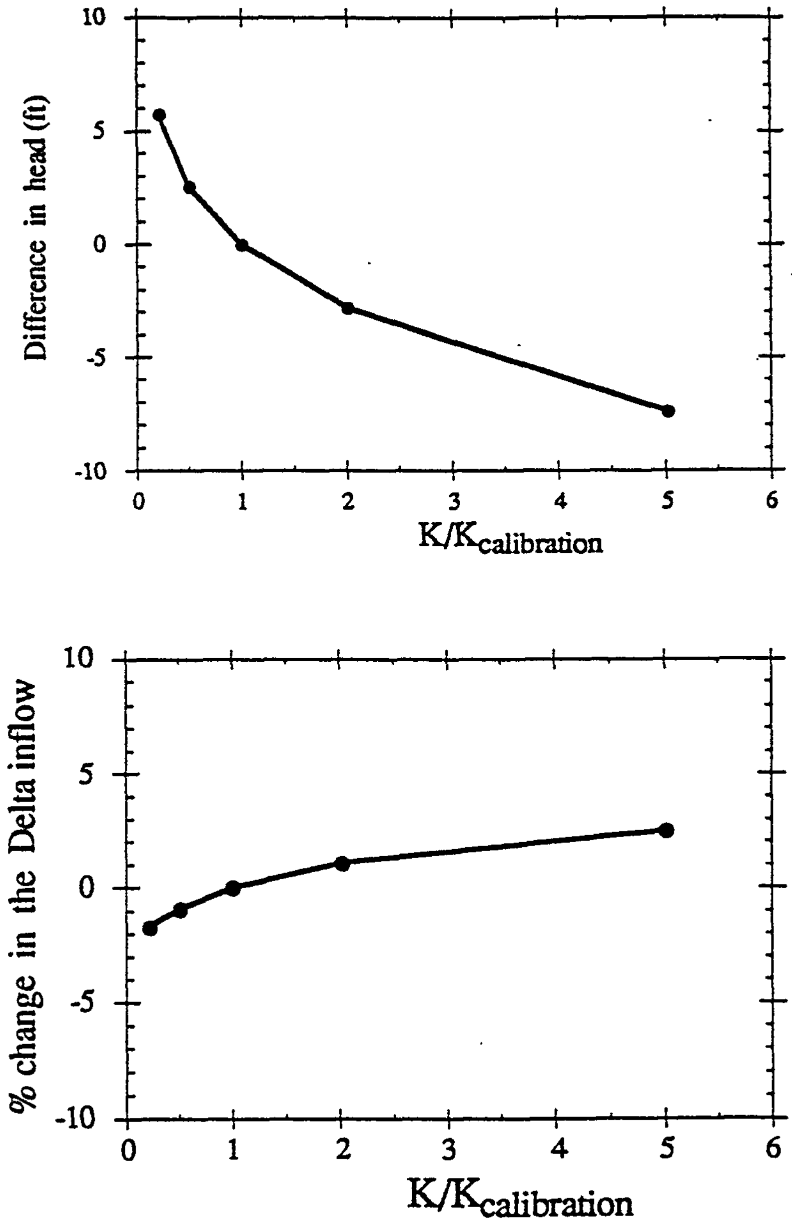


FIGURE 4.5(a)

SENSITIVITY ANALYSIS FOR
HYDRAULIC CONDUCTIVITY (K)

C — 0 3 8 4 7 5

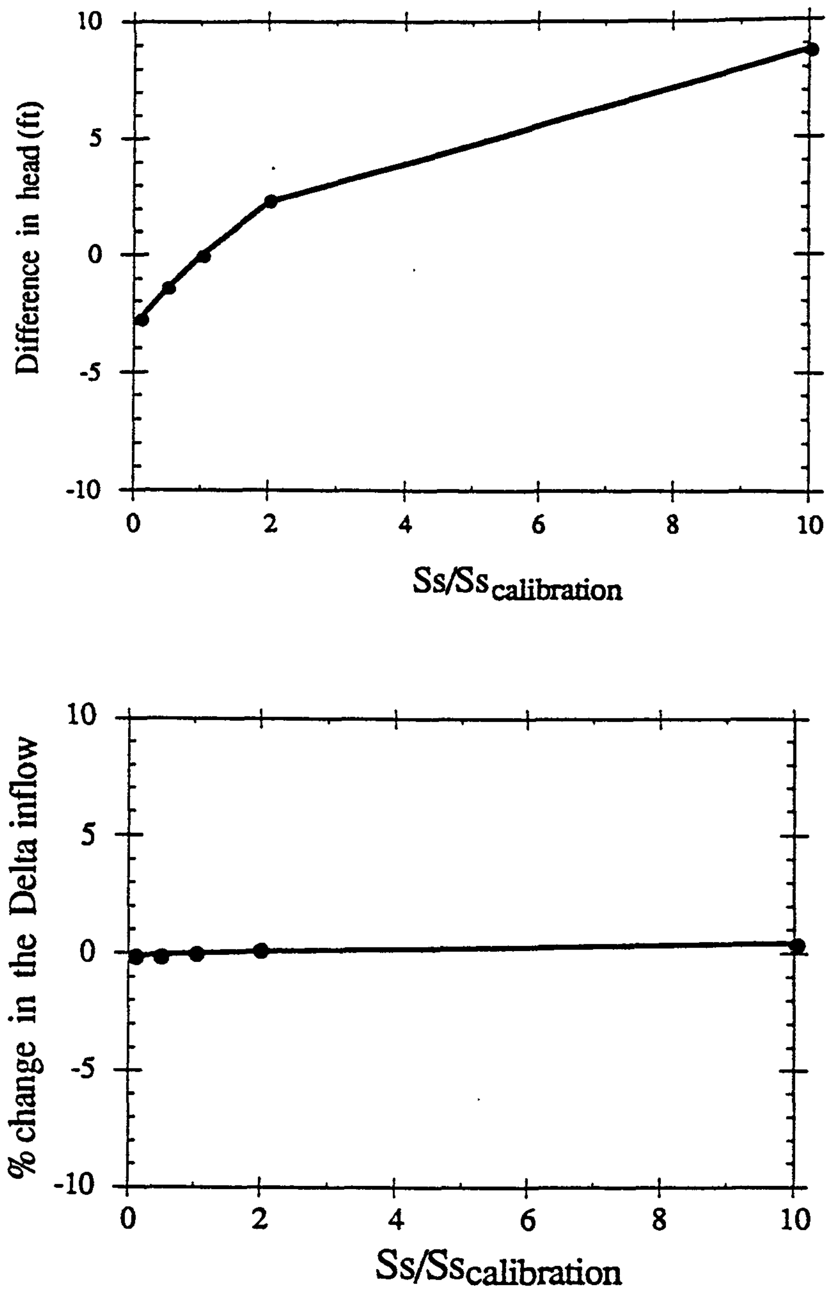
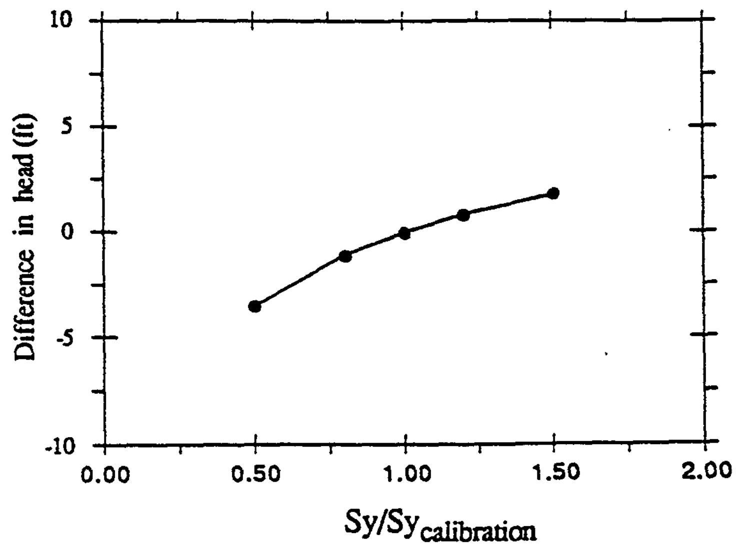


FIGURE 4.5(b)

SENSITIVITY ANALYSIS FOR
STORAGE COEFFICIENT (Ss)



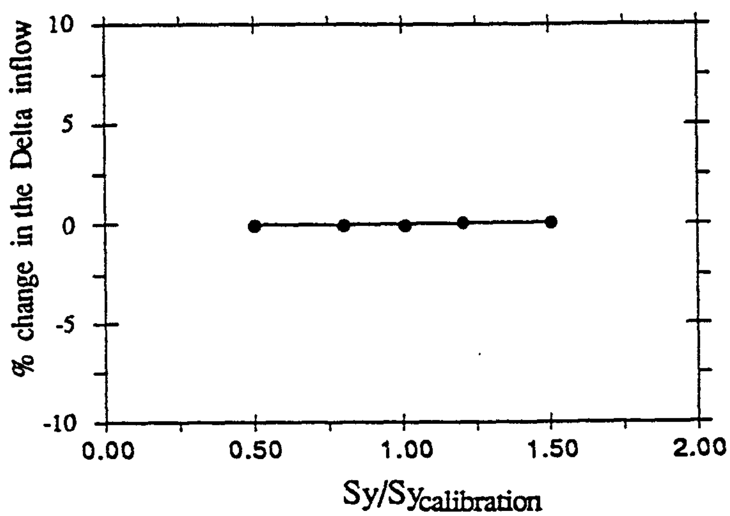
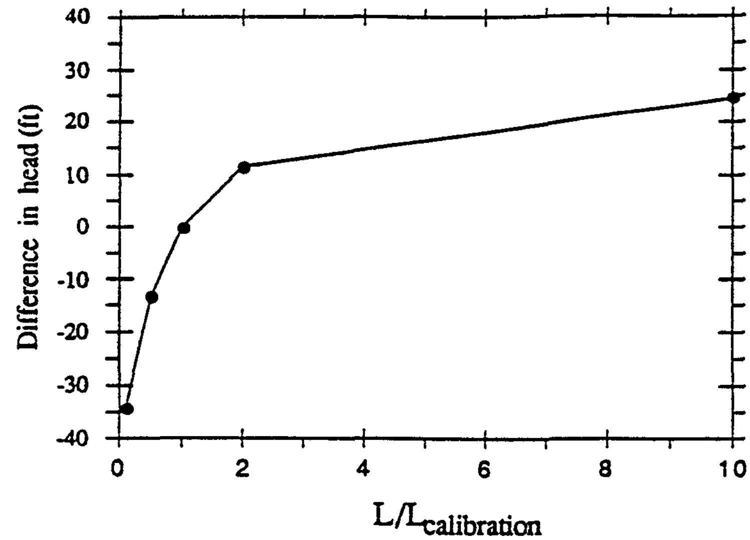


FIGURE 4.5(c)

SENSITIVITY ANAYLSIS FOR
SPECIFIC YIELD (Sy)



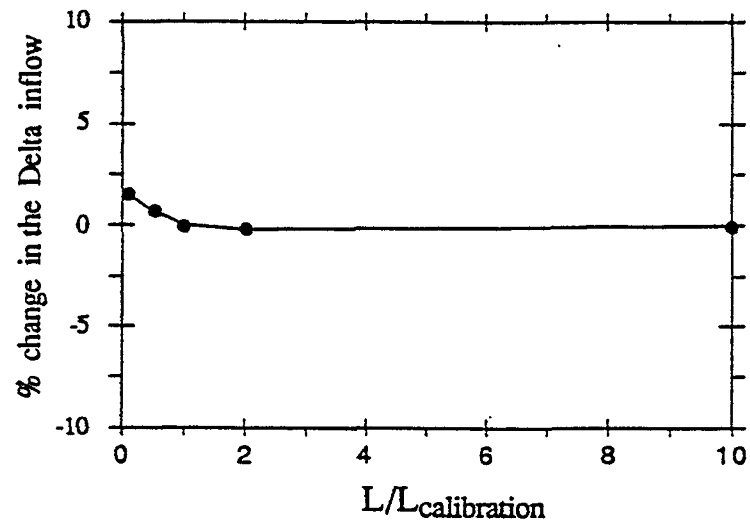
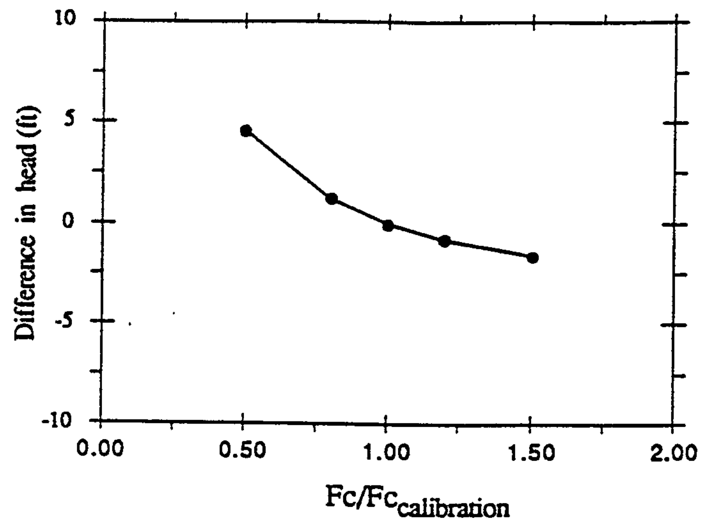


FIGURE 4.5(d)

SENSITIVITY ANALYSIS FOR
LEAKANCE(L)



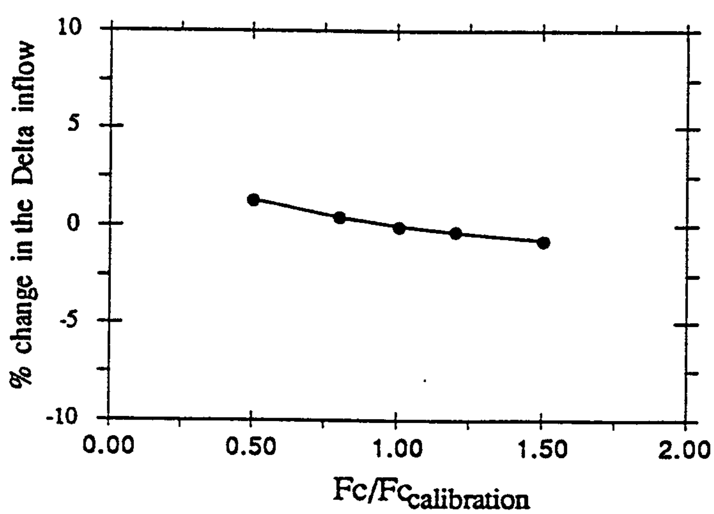


FIGURE 4.5 (e)

SENSITIVITY ANALYSIS FOR
FIELD CAPACITY (Fc)

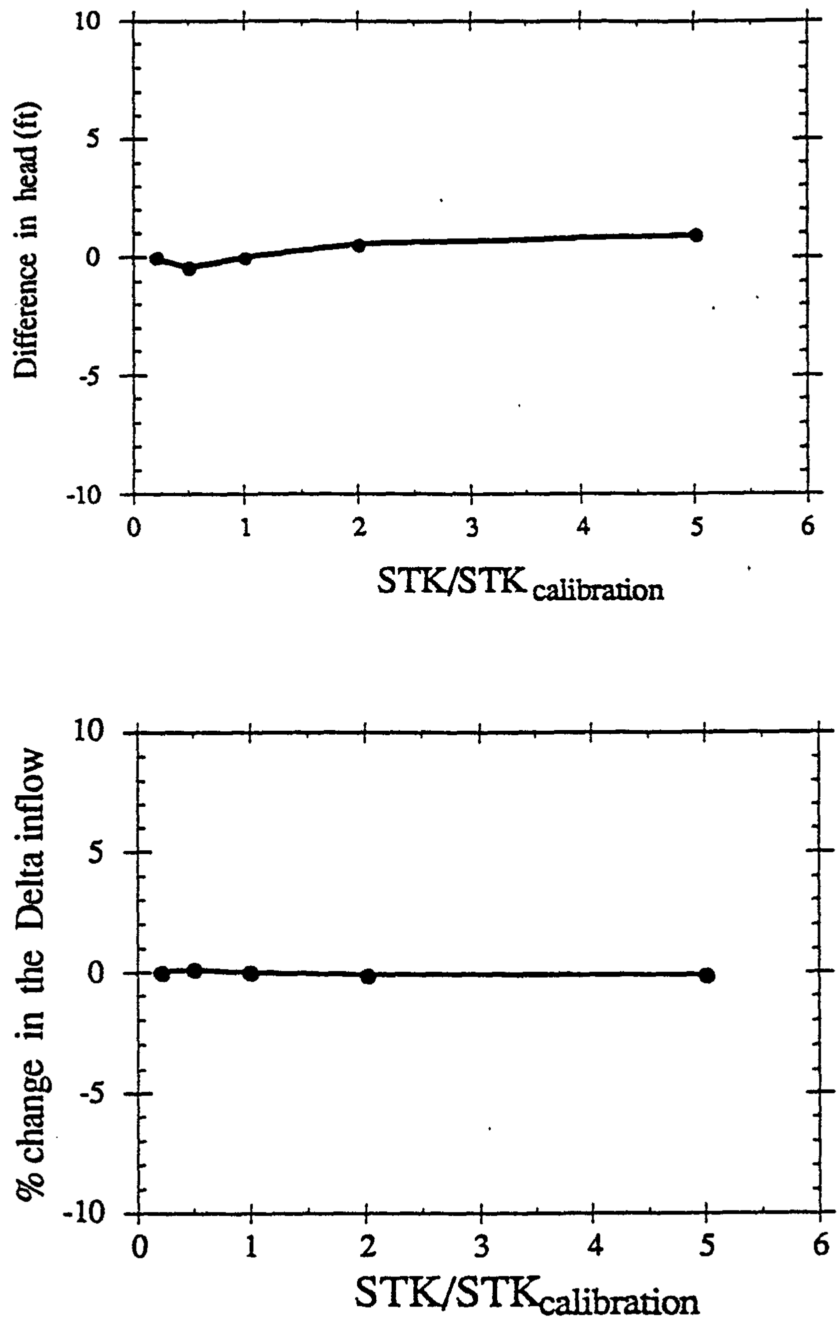
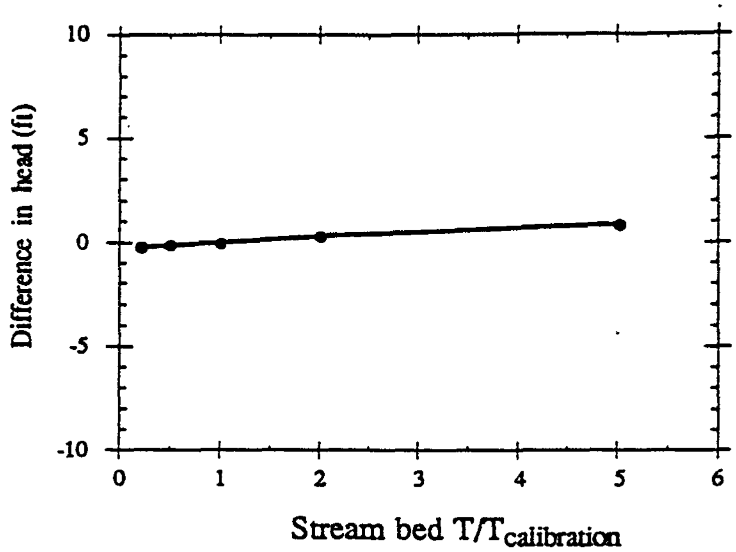


FIGURE 4.5(f)

SENSITIVITY ANALYSIS FOR
STREAM BED CONDUCTIVITY
(STK)



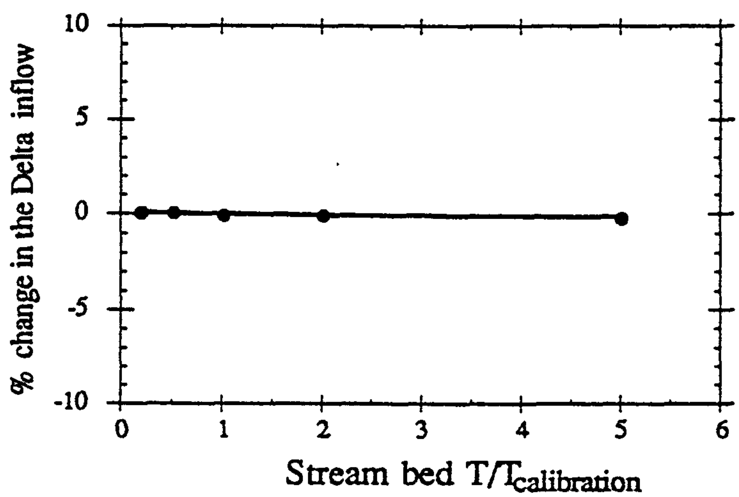


FIGURE 4.5(g)

SENSITIVITY ANALYSIS FOR
STREAM BED THICKNESS (T)

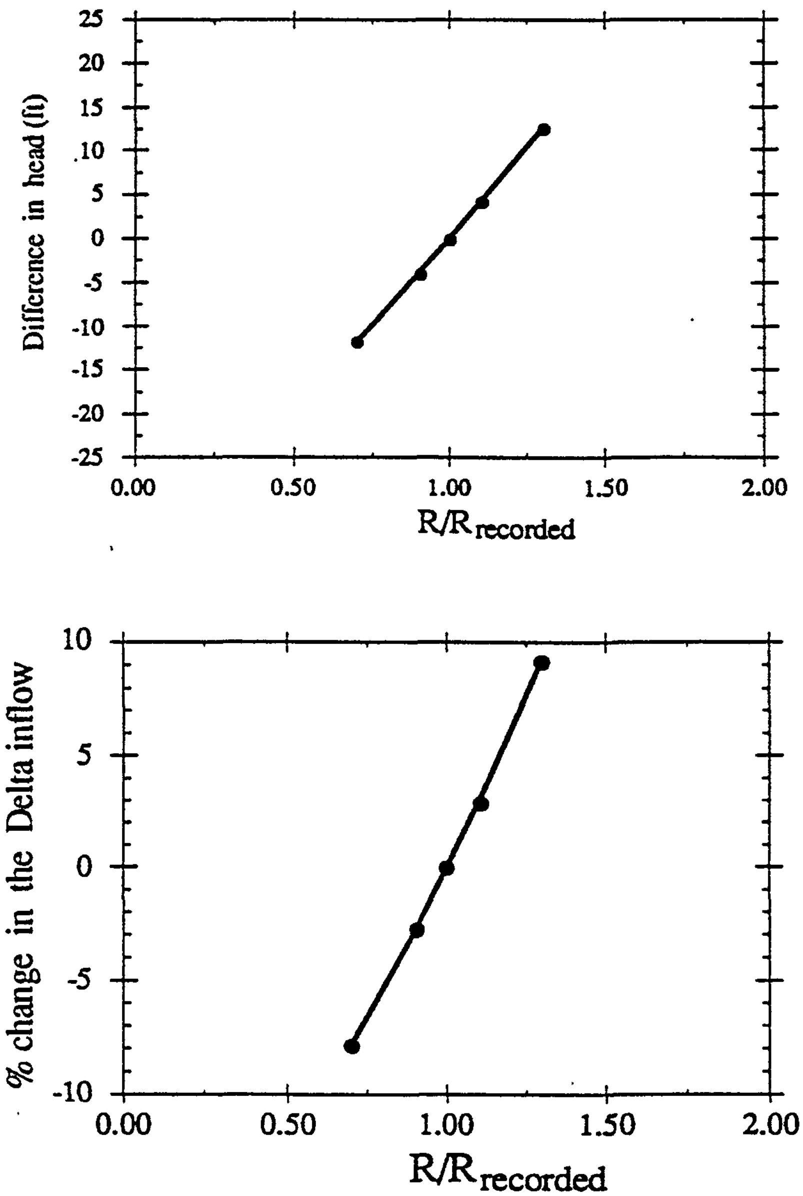
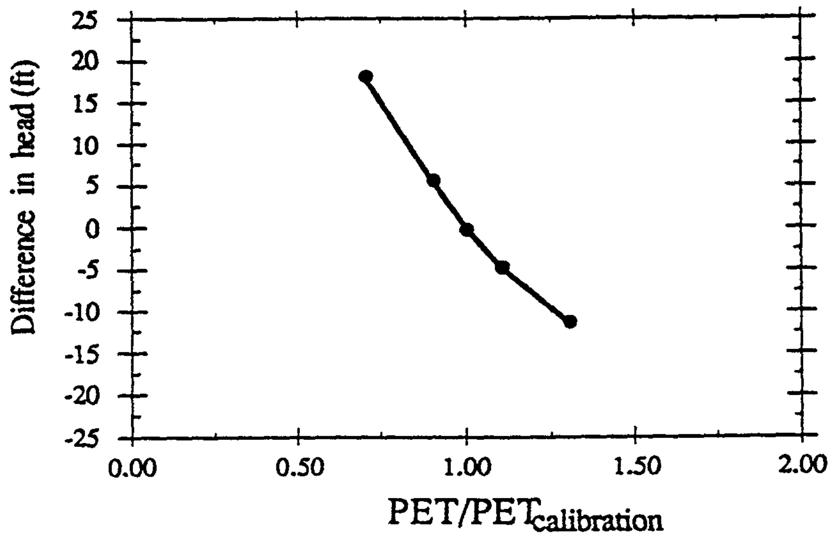


FIGURE 4.5 (h)

SENSITIVITY ANALYSIS FOR RAINFALL (R)



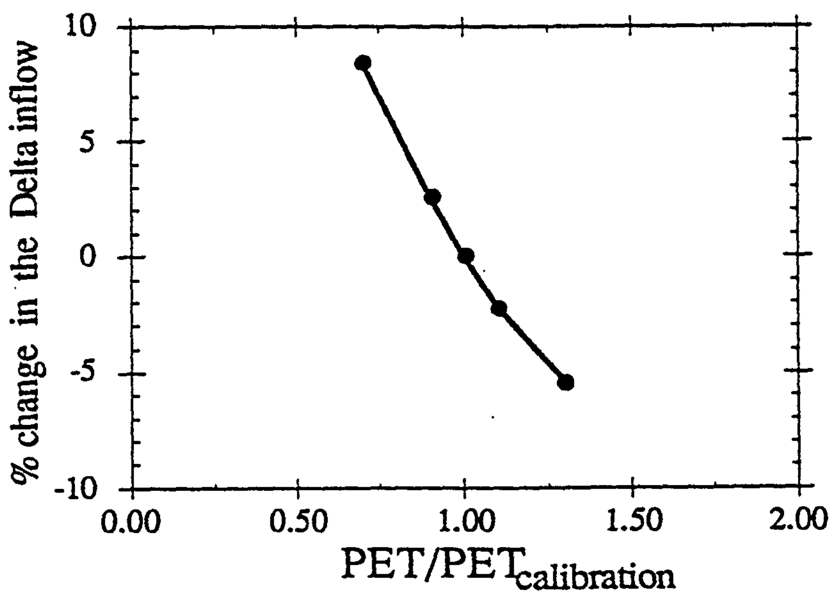
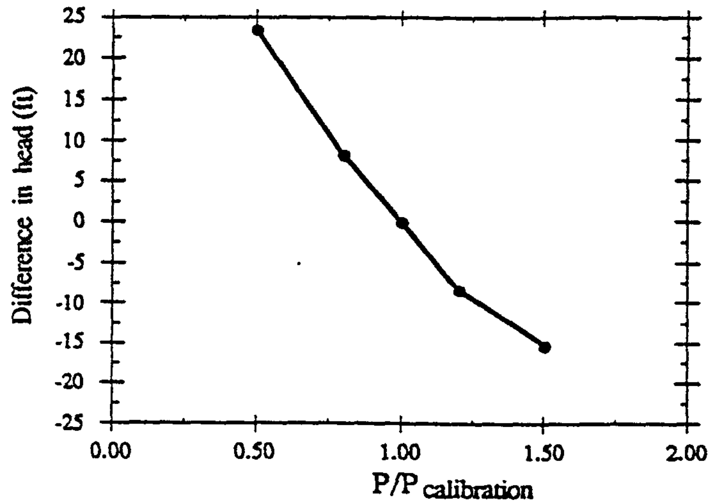


FIGURE 4.5 (i)

SENSITIVITY ANALYSIS FOR POTENTIAL EVAPOTRANSPIRATION (PET)



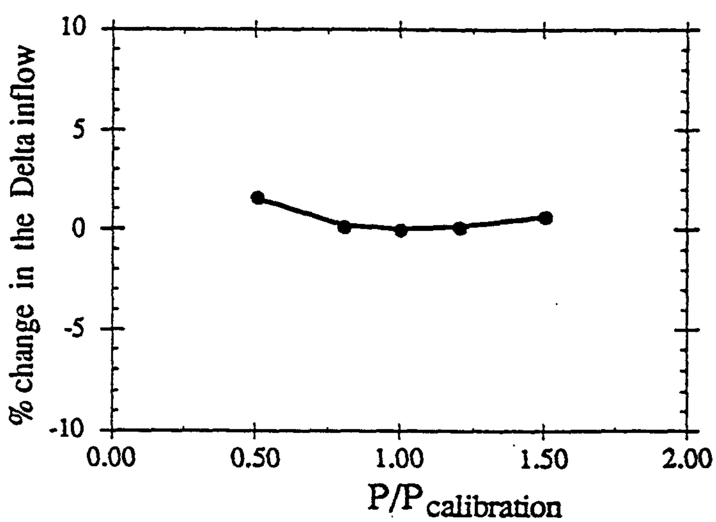
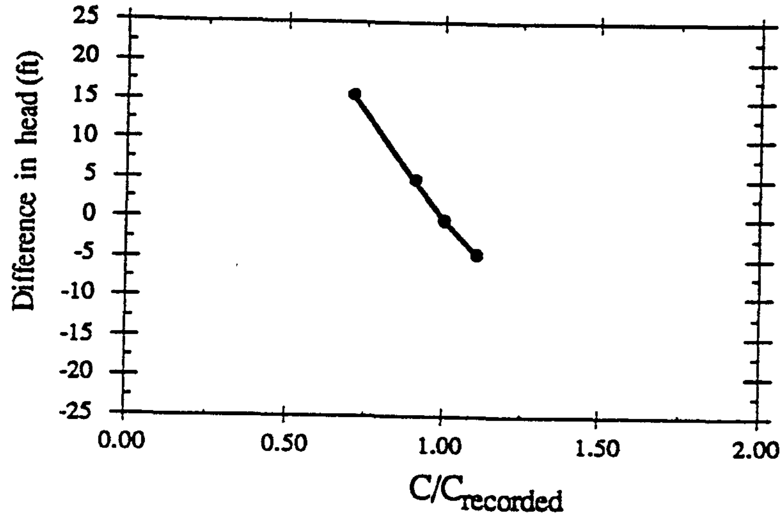


FIGURE 4.5 (j)

SENSITIVITY ANALYSIS FOR
GROUNDWATER PUMPING (P)

C — 0 3 8 4 8 4



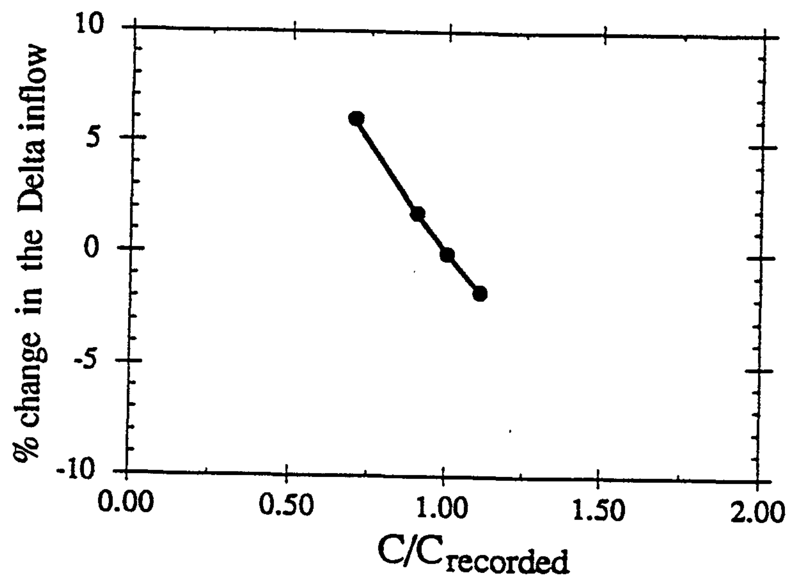


FIGURE 4.5 (k)

SENSITIVITY ANALYSIS FOR
CROP ACREAGE (C)

Section 5

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5.0 FUTURE MODEL USE

5.1 LINKAGE WITH RESERVOIR SIMULATION MODEL

The CVGSM does not include a reservoir simulation component. To project future flows or to estimate water availability in the Central Valley, the model needs to be operated in conjunction with PROSIM or DWRSIM -- reservoir operation models developed by USBR and DWR, respectively. To provide a link to these reservoir simulation models, CVGSM provides special outputs containing

- Agricultural and urban water demands
- Direct runoff from rainfall
- Surface water return flow from irrigation-applied water
- Streamflow gain or loss due to interaction with groundwater
- Groundwater pumping
- Streamflow diversion requirements and shortages.

The above information can be generated for any number of element groups. They do not need to coincide with the subregions.

For projection runs, the model may be initially operated with assumed upstream flows. A reservoir operation model would then be applied to adjust upstream flows and to supplement downstream shortages. It may require several interactive executions between the CVGSM and a reservoir operation model until satisfactory results are obtained.

5.2 OTHER USES

The CVGSM model is a comprehensive hydrologic model that can be used in large scale as well as small scale water management plans. At its present stage of development, it has numerous components and features that can be effectively used in estimating the annual safe yield of groundwater from the aquifer and in evaluating the multifarious impacts of groundwater use within and outside a particular area of interest as discussed below.

Safe Yield Analysis

Safe yield can be defined as the amount of water which can be withdrawn annually from a groundwater basin without producing an undesirable result such as impairment of the aquifer as a water source due to overdraft, contamination, or increased pumping cost due to higher lift. All the components of the safe yield (such as recharge, precipitation, evapotranspiration, subsurface outflows, etc.) computation are part of the model output files that can be readily used in making safe yield estimates for any region of interest. However, it should be mentioned that the elements of the CVGSM are large, averaging 14 square miles in area. Consequently, model results for groundwater levels or hydrologic budgets represent regional values. It may be necessary to refine model grids and associated data to obtain more accurate and detailed results for a particular area of interest.

Site Specific Model

The hydrology of a particular area of interest within a regional groundwater basin is substantially modulated by the natural and human activities on the entire basin. The effects of the activities outside the area of interest are transferred through the subsurface and surface boundary fluxes. Estimation of the boundary fluxes is the biggest impediment to the site specific application of an integrated groundwater surface water model. However, by incorporating this time varying hydrologic component (i.e. boundary fluxes) as an output of the CVGSM, the site specific application of the model has been made easily attainable. The boundary fluxes at each boundary node can be obtained from a coarse-grid regional model and subsequently used in the fine-grid site specific model for detailed analysis. Also, the CVGSM's input/output structure allows for a detailed analysis of a smaller region of interest within a regional groundwater basin by processing the hydrologic budget outputs on an element group basis.

Impacts of Groundwater Use

Groundwater use directly affects groundwater levels, streamflows, land subsidence, and water quality. The CVGSM can be used in estimating and evaluating these impacts of groundwater use on a local and regional scale. The groundwater level fluctuations within a region can be directly estimated from the CVGSM as the groundwater head values at every finite element node are computed at each simulation time step by solving the differential equation of groundwater flow. Thus the time space variation of groundwater levels under historic and projected water use can be quantified by the model. The streamflows are computed at each stream node together with the stream reach gains and losses through interaction with groundwater and return flow from surface water use in the vicinity. Thus the impacts of future groundwater use on streamflows can be estimated by applying CVGSM to the area of interest.

Groundwater use affects the water quality of the underlying aquifer, of pumped water, and of streamflows. Since the subsurface flows and the leakage from layer to layer is computed in the CVGSM, this information can be used to infer about the potential degradation of water quality due to excessive groundwater use. Water quality is not directly simulated through the CVGSM; however, this detailed flow model with all its inherent features is a first step towards a regional water quality simulation model. The impacts of groundwater use on water quality is discussed in Appendix A in the context of the Central Valley groundwater basin.

Excessive groundwater pumpage has often been cited as a major cause of land subsidence in areas of heavy agricultural use. The CVGSM does not incorporate any program module to simulate land subsidence as a result of groundwater level fluctuations. However, it gives the necessary information which can be correlated with the measured land subsidence in the past to predict subsidence potentials under projected groundwater use. The impacts of groundwater use on land subsidence is discussed in Appendix B in the context of the Central Valley of California.

5.3 SUMMARY AND CONCLUSION

A finite element hydrologic simulation model was developed and applied to the Central Valley of California. The application model is named the Central Valley Groundwater Surface Water Model (CVGSM) as it simulates both the groundwater and surface water flows and their interactions. The 59-year hydrologic period (1922-80) simulated by the model was found to perform satisfactorily when compared with the historic measurements of groundwater levels and streamflows. An extensive data collection, verification and validation effort was undertaken as a part of this study which resulted in substantial enhancement and revision of the Central Valley's hydrologic database maintained by different federal, state and local agencies. The 20,000 square mile study area was subdivided into 21 model subregions, incorporating the California Department of Water Resources' planning subareas, for the purpose of analyzing a small scale water balance within each subregion. The input data for the model was developed on a detailed spatial scale, either on a nodal or elemental basis, with an average element size of 14 square miles. The model was subsequently calibrated against historic measurements by adjusting the model parameters. Adjustment of these parameters were required due to their inherent random nature as they cannot be deterministically evaluated from topographic, climatic or hydrogeologic characteristics of the groundwater basin. Sensitivity analyses of these parameters were performed to enhance the understanding of the importance and impacts of different parameters on the model results. These sensitivity analyses were further extended to include some hydrologic variables to underscore their relative significance in a regional hydrologic simulation model.

The CVGSM can be used as an effective planning tool to explore and evaluate various water management strategies and options in the Central Valley. However, the limitations of the hydrologic data available for the Central Valley should not be overlooked. The model was calibrated with the most comprehensive database that can be developed by utilizing and validating all the hydrologic data that was available at the time of this study. Based upon the calibration results, it can be said that the CVGSM has passed the test of verification and validation within the scope of this regional study in the context of the area of application. The input data base for the model can be refined and incorporated into the model as more data becomes available. For site specific studies, the model grid can be refined to incorporate the hydrologic data available on a smaller spatial scale. The CVGSM, by virtue of its input data driven attributes and its adaptability to data and grid refinement, holds promises for future application to meet the needs of conjunctive use operation on local as well as regional scale in the face of growing concern for "optimal" use of valuable surface water and groundwater resources.

Appendix A

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APPENDIX A

WATER QUALITY INVESTIGATION

A.1 INTRODUCTION

The water quality was not simulated by the Central Valley Groundwater and Surface Water model, but was investigated separately. Although the Central Valley groundwater quality is influenced mainly by the basin's geology, conjunctive use operations (recharge and pumping) in the Valley may also affect groundwater quality. The effects of recharge and pumping on groundwater quality is discussed here and is followed by a review of the existing groundwater quality in the Central Valley. The latter information is used to identify potential areas where groundwater quality may limit conjunctive use operations. Summary statistics of selective groundwater quality parameters are described on a county by county basis. Some parameters are also discussed in relation to aquifer depth in each county. The water quality data was compiled from the U.S. Environmental Protection Agency's STORET. The study limitations are outlined below.

A.2 LIMITATIONS OF THE STUDY

A regional assessment of groundwater quality for a large area such as the Central Valley is bound to have limitations that are important to note at the outset. Templin (1984) listed the shortcomings of designing an ideal groundwater quality monitoring network for the San Joaquin Valley, most of which are also applicable to this regional study. The size of the study area and the extensive development of the Central Valley groundwater makes it difficult to identify active groundwater quality monitoring networks. As a result, the collection and compilation of data in a unified format is not straightforward. A general lack of depth and perforation information on the wells has made it difficult to identify the aquifers from which particular wells were pumping from. This problem was partially overcome by using some San Joaquin Valley wells mentioned in Templin (1984) which had water quality information in STORET. A well inventory from STORET for some counties in San Joaquin Valley and for all counties in Sacramento Valley was also used to select wells that supplemented the USGS network wells. Depth and perforation data on those wells were sought from DWR. Other related problems were that DWR did not have depth and/or perforation information on several wells selected from STORET or that the wells selected from STORET and from the USGS network were not monitored for all water quality parameters discussed herein.

Because of the limitations in identifying a consistent groundwater quality monitoring network, only a countywide assessment of groundwater quality is made and site specific areas of poor groundwater quality have not been identified. Additional sources of published information that would assist in future site specific groundwater quality investigations are listed in the reference section.

A.3 THE EFFECTS OF CONJUNCTIVE USE ON GROUNDWATER QUALITY

Conjunctive use involves recharge of surface water supplies into groundwater during periods of high surface supplies and pumping of groundwater during periods of low surface supplies. Groundwater quality is influenced mainly by the chemical properties of the aquifer and the length of time the water is in contact with the rock. For alluvial and terrace deposits, groundwater quality is also influenced by the quality of recharge waters. Specifically, the quality of the alluvial groundwater is affected by the quality of surface waters recharging into the aquifer. Conjunctive use operations can also be limited by the effects of overpumping on groundwater quality.

The Effects of Recharge on Groundwater Quality:

The quality of recharge water is important for groundwater management since poor quality recharge water can contaminate groundwater and limit its use. Also surface water of good quality is of limited use if it is recharged in areas of poor quality groundwater or in areas where soils contain high concentrations of introduced or naturally occurring contaminants.

The thickness of the freshwater containing deposits ranges from 0 ft at the edges of the Valley to about 3,000 ft in the Sacramento Valley and to 4,700 ft in the southern end of the San Joaquin Valley (Page, 1986). The safe yield of the aquifer varies across the Valley depending on the hydrogeologic conditions. It is dependent on the presence of permeable soils, depth to the confined strata, use of recharge facilities, and presence of large well fields which redirect groundwater flows.

Recharge in the Central Valley occurs through natural, incidental and artificial means. Natural recharge sources include precipitation, streamflow, and surface water bodies such as reservoirs, lakes, wetlands, etc. In general, natural recharge sources have little adverse effect on groundwater quality except when recharge occurs in areas where soils have been contaminated.

Incidental recharge sources includes man-made activities such as irrigation, septic tanks, cesspools, leaky water mains, sewers, landfills, waste-disposal facilities and canals. These sources pose a more serious threat to groundwater quality than others. On a regional scale, the irrigation return flow is by far the largest incidental recharge source in the Central Valley. Irrigation increases the salinity of the return flows due to the addition of salts by dissolution during the irrigation process, and due to the presence of fertilizers and/or soil amendments, and due to salt concentration as a result of evapotranspiration of applied water. The application of pesticides and other chemicals to control, destroy or mitigate farm pests may also affect the quality of irrigation return flows recharging into the groundwater.

Artificial recharge methods include augmenting groundwater supplies by spreading water over land surface, recharging through pits and wells, and pumping to induce recharge from surface water bodies. Favorable areas for artificial recharge in the San Joaquin Valley include alluvial fans in the vicinities of the Kern, San Joaquin, Kings, Merced, Tuolumne and Stanislaus rivers. Artificial recharge methods have been used in the Madera, Tulare and Kern counties. Potential areas for artificial recharge are discussed in DWR (1980).

The Sacramento Valley groundwater aquifer is recharged by subsurface lateral inflow from adjacent areas, by deep percolation of applied irrigation water and precipitation, and by leakage from streams and canals. The primary recharge areas under natural conditions are along the valley margins, especially in the Stony Creek and Thomes Creek areas in the northwestern part of the Sacramento Valley.

The San Joaquin Valley groundwater aquifers are separated in places by widespread thick and fine grained layers. These layers of silt and clay are effective confining layers, especially in the Tulare lake bed area. The Corcoran Clay forms the principal confining layer extending across the Valley, although it is not continuous at the edges of the valley. Lateral flows of groundwater is the primary mechanism of recharge to the confined aquifer. Groundwater flows horizontally in the unconfined and confined layers towards a "trough" near the western side. The Corcoran Clay reduces the volumes and rate of recharge into the confined aquifer.

Depth to groundwater in the Valley's alluvial aquifers is important because of the potential for rapidly influencing the quality of groundwater by activities on the land surface. In the Sacramento Valley, the depth to groundwater varies from 0 to 200 ft. Depth to groundwater in the San Joaquin Valley varies between 2 to 800 ft. It is related to the local occurrence of various subsurface strata and surface topography. Plate 4 in Templin (1984) shows the boundary of present and potential drainage problem areas where depth to the perched water table ranges from 0 to 20 ft.

<u>The Effects of Pumping on Groundwater Quality:</u>

Groundwater pumping can also adversely affect groundwater quality. Overpumping can cause a horizontal or vertical migration of poor quality waters into areas of good quality waters. Interaquifer movement can also occur if a conduit for the movement exists when there is a difference in hydraulic head

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across aquifer boundaries. Polluted water can travel across aquifers where well screens, perforated casing, or open borehole, interconnects two separate aquifers, or where surface casing has not been sealed properly. In the San Joaquin Valley, there are several hundreds, if not thousands, of wells that are perforated in more than one aquifers and could act as conduits for interaquifer movement.

Overpumping can also induce vertical movement of saline water into the fresh water in areas where fresh water overlies saline waters. Connate waters exist below the base of the fresh groundwater layer. In the Sacramento Valley, the base of the freshwater (electric conductivity less than 3,000 uS/m) has been identified by Berkestresser (1973). The depth of the base of fresh groundwater in the Sacramento Valley ranges from 0 to 3,200 ft below mean sea level. In the San Joaquin Valley, the base of the freshwater ranges from 0 to 15,000 ft below mean sea level. Although there have been concerns about the effects of pumping on raising the base of the freshwater in parts of the San Joaquin Valley, there is little data available to either support or reject these concerns.

Overpumping near coastal areas can induce seawater intrusion, i.e. the movement of coastal saltwater into inland fresh groundwater. Under natural conditions, fresh groundwater in coastal aquifers is discharged into the sea. Overpumping, however, can cause seawater to advance inland within the aquifer. Groundwaters of the western San Joaquin County, especially near Stockton, have been suspected to be intruded by saline waters from the Delta. The investigation by Brown and Caldwell (1985) concluded that historical chloride concentrations did not indicate a consistent increasing trend.

A.4 EXISTING GROUNDWATER QUALITY INVENTORY

This section summarizes groundwater quality in the Central Valley on a county scale. It describes selective water quality constituents found in the groundwater of all sixteen counties within the model boundary. The water quality parameters discussed here include those constituents that affect agricultural productivity and others that are noted to be in high concentrations and known to affect human health and wildlife.

Groundwater quality data compiled since 1971 in STORET have been summarized in three inventories. The first inventory classifies TDS concentrations in groundwater of each county. The second inventory contains summary statistics on eight water quality parameters: chloride, sodium, sulfate, nitrate, boron, arsenic, selenium, and DBCP found in groundwater. The first two inventories do not consider information on individual wells or aquifer depths from which the data were compiled from, but contain an aggregate of data compiled in each county between 1971 to the present. Whereas the third inventory incorporates depth information. It contains TDS, chloride, sodium, calcium, and sulphate data by

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depth (categorized according to the three model layers) in each of the sixteen counties.

Inventory #1: Total Dissolved Solids Classifications

The recommended TDS concentration for municipal and some industrial supply is 500 mg/l. The effects of TDS in irrigation water on crops depends on crop types. US Environmental Protection Agency has recommended a TDS concentration of 700 mg/l for irrigation waters.

For this inventory, four classes of mean TDS concentration are identified: below 700 mg/l (Class I), 700 to 1,500 mg/l (Class II), 1,500 to 3,000 mg/l (Class III), and greater than 3,000 mg/l (Class IV). Table A.1 contains TDS classifications for groundwater samples taken from 16 Central Valley counties.

Class I TDS concentrations were found in all Shasta county groundwater samples; in more than 99 % of Tehama, Glenn and Tulare county samples; in 90 to 99 % of Butte, Sutter, Sacramento, and Madera county samples; in 80 to 89 % of Colusa, Yolo, San Joaquin, Stanislaus and Kern county samples; in 72 % of Fresno county samples, 57% of Kings county samples; and 6 % of Merced county samples.

Class II TDS concentrations were found in less than 1 % of Tehama, Glenn, Butte and Tulare county samples; 1 to 10 % of Sutter, Sacramento, Madera, Merced, and Fresno county samples; and in 11 to 20 % of Colusa, Yolo, San Joaquin, Stanislaus, Kings, and Kern county samples.

Class III TDS concentrations were found in about 1 % of Butte and Sutter county samples, in 2 to 5 % of Colusa, Sacramento, San Joaquin, Stanislaus, Madera, Fresno, Kings, and Kern county samples; and in 18 % of Merced county samples.

Class IV TDS concentrations were found in: less than 1 % of San Joaquin county samples; between 1 and 2 % of Kern county samples; 12 % of Fresno county samples; 21 % of Kings county samples; and 68 % of Merced county samples.

Inventory #2: General Water Quality Data

The second inventory contains summary information on groundwater chlorides, sodium, sulfate, nitrate, boron, arsenic, selenium, and DBCP by county. Each parameter is discussed below.

Chloride:

Chloride concentration in excess of 100 mg/l imparts a salty taste, and even higher concentrations are corrosive to pipes, but it does not pose a health hazard. The

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TABLE A.1

TOTAL DISSOLVED SOLIDS (mg/l) CLASSIFICATION IN SIXTEEN CENTRAL VALLEY COUNTIES

(Period of Record: 1971-Present)

	I <700 mg/L			II 700-1500 mg/L			III 1500-3000 mg/L			VI >3000 mg/L		
County	N	#Well	Mean	N	#Well	Mean	N	#Well	Mean	N	#Well	Mean
Shasta	130	53	183	0	0	-	0	0	-	0	0	-
Tehama	237	137	239	1	1	732	0	0	-	0	0	-
Glenn	315	182	297	2	2	876	0	0	-	0	0	-
Butte	588	200	222	3	3	872	7	2	1954	0	0	-
Colusa	179	147	360	23	16	996	4	4	1748	0	0	-
Sutter	147	118	338	13	10	918	2	2	1700	0	0	-
Yolo	146	122	390	27	21	981	0	0	-	0	0	-
Sacramento	233	212	230	14	13	985	6	4	2290	0	0	-
San Joaquin	732	451	322	137	89	1033	47	31	1939	1	1	3050
Stanislaus	89	85	360	14	14	972	3	3	2350	0	0	-
Merced	213	99	309	252	57	1109	628	75	2267	2341	265	12267
Madera	68	66	333	4	4	805	3	3	2161	0	0	-
Fresno	282	193	240	39	36	982	21	17	1954	48	21	10124
Kings	59	54	332	19	17	921	3	3	2097	22	2	5903
Tulare	584	208	192	3	3	767	0	0	-	0	0	-
Kern	1846	872	307	238	172	995	78	65	1842	23	22	5102

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recommended municipal and industrial water quality standard for chlorides is 250 mg/l. Chlorides in high concentrations can be toxic to plants; however, salinity impairs growth before chloride concentrations can reach toxic levels. Chloride concentrations of almost 700 mg/l can be used on most crops without incurring toxic effects.

Table A.2(a) contains summary statistics of chloride concentrations in the groundwater of all sixteen counties. Mean chloride concentration in Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Yolo, Sacramento, San Joaquin, Stanislaus, Madera, and Tulare county samples was less than 100 mg/l. In Kern and Kings county samples, mean chloride concentration was between 100 and 250 mg/l. Fresno county samples had mean chloride concentration of 389 mg/l. While Merced county samples had the highest mean chloride concentration of 1,798 mg/l.

Maximum chloride concentration in samples from Shasta, Tehama, and Glenn county was less than 250 mg/l; from Butte and Colusa county was between 250 and 500 mg/l; from Sutter, Yolo, and Tulare county was between 500 and 1,000 mg/l; from Sacramento and Madera county was between 1,000 and 1,500 mg/l; from Stanislaus and San Joaquin county was between 2,000 and 3,000 mg/l; from Fresno was 9,200 mg/l; and 16,000 mg/l, 25,280 mg/l, and 44,000 mg/l in samples from Kings, Merced, and Kern counties respectively.

<u>Sodium:</u>

There are no Federal or State drinking water standards for sodium, but the National Academy of Sciences (NAS) has two advisories. NAS recommends a 20 mg/l limit for people on a severely restricted diet, and a 100 mg/l limit for people on a moderately restricted diet.

Table A.2(b) contains summary statistics of sodium concentrations in the groundwater of all sixteen counties. Only Shasta and Butte county samples had a mean sodium concentration of less than 20 mg/l. Tehama, Glenn, Colusa, Sutter, Yolo, Sacramento, San Joaquin, Stanislaus, Madera, Tulare and Kern county samples had a mean sodium concentration of 20 to 100 mg/l. Merced and Fresno county samples had a mean sodium concentration of 100 to 200 mg/l, while Kings county samples had a mean concentration of 653 mg/l. Maximum sodium concentrations in samples from all counties, except Merced, Fresno and Kings, were between 60 and 600 mg/l. Merced had a maximum of 2,900 mg/l, Fresno 17,000 mg/l and Kings 29,000 mg/l.

<u>Sulfate:</u>

Water having sulfate concentration of about 500 mg/l tastes bitter and water having sulfate concentration in excess of 1,000 mg/l may be cathartic.

Acclimatization to high sulfate concentration is such that sulfate is not usually considered a health hazard. The recommended drinking water quality and food canning standards for sulfate is 250 mg/l. High sulfate concentration is detrimental to plants because it can limit plant uptake of calcium. The State Water Resources Control Board guidelines states a 480 mg/l sulfate concentration in water to be of excellent to good quality for irrigation, and a 960 mg/l sulfate concentration as injurious to unsatisfactory for irrigation.

Table A.2(c) contains summary statistics of sulfate concentrations in all sixteen counties. Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Yolo, Sacramento, San Joaquin, Stanislaus, Madera, and Tulare county samples had mean sulfate concentration of less than 100 mg/l. Kern county samples had a mean sulfate concentration of 289 mg/l, while Fresno, Kings and Merced counties had mean sulfate concentrations of 1,493 mg/l, 1,684 mg/l and 3,450 mg/l respectively.

Maximum sulfate concentration in Shasta, Tehama, Glenn, Sacramento and Madera counties were less than 100 mg/l, and in Butte, Colusa, Sutter, Yolo, and Tulare counties, the maximum is between 100 and 900 mg/l. Stanislaus and San Joaquin counties had a maximum concentration of 1,000 to 2,000 mg/l. Kern county had a maximum sulfate concentration of 15,000 mg/l, while Merced and Fresno counties had a maximum of 30,000 to 40,000 mg/l. Kings county had the highest sulfate concentration of 65,000 mg/l.

Boron:

Boron is not regulated in drinking water, but it is a critical element in irrigation water. Boron concentration of up to 0.5 mg/l is considered essential for plant growth, however, concentrations greater than 0.75 mg/l is considered to be toxic to sensitive plants. The NAS has categorized plants on the basis of their response to boron concentrations: sensitive (<1mg/l), semitolerant (1-2mg/l), and tolerant (>2mg/l).

Table A.2(d) contains summary statistics of boron concentrations in all sixteen counties. (Note: STORET reports boron concentrations in ug/l.) The mean boron concentration in Shasta, Tehama, Glenn, Butte, Colusa, Sutter, Sacramento, San Joaquin, Stanislaus, Madera, Tulare and Kern county was less than 0.5 mg/l. Mean boron concentration in Yolo county was 0.85 mg/l, in Fresno county it was 1.99 mg/l, and in Kings and Merced counties, it was 4.2 mg/l and 12.1 mg/l, respectively.

Maximum boron concentration in Shasta, Tehama, Butte, Colusa, Sutter, and Madera counties was less than 0.5 mg/l; in Sacramento and Tulare counties was between 0.5 and 0.53 mg/l; in Glenn county 1.1 mg/l; in San Joaquin, Stanislaus, Kern, and Yolo counties the maximum concentration was 2 to 4 mg/l; in Merced and Kings county 39 mg/l; and in Fresno county it was 130 mg/l.

Nitrates:

Nitrates are common contaminants in the groundwater of many rural communities in California and are becoming increasingly widespread because of agricultural activities and sewage disposal on or below the land surface. Nitrates can enter the groundwater through either the conversion of naturally occurring or introduced organic nitrogen or ammonia. The primary drinking water quality standard for nitrate is 45 mg/l. Excess nitrates cause methemoglobinemia in infants (blue babies syndrome). Nitrates are converted to nitrites in the intestines and it inhibits the body's ability to ingest oxygen.

For most agricultural use, nitrate is considered an asset because of its value as a fertilizer. However, high nitrate concentrations may have adverse effects on certain crops such as sugar beets, apricots, grapes, citrus, and avocados. Increasing problems can be detected from nitrate concentration of 5 mg/l with severe problems occurring in concentrations above 30 mg/l.

Table A.2(e) contains summary statistics of nitrate concentrations in groundwater in all sixteen counties. Mean nitrate concentration in Shasta, Sacramento, and Kings counties was less than 5 mg/l; in Butte, Colusa, Yolo, San Joaquin, and Madera counties was between 5 and 10 mg/l; in Tehama, Glenn, Merced, Fresno, Tulare, and Kern counties was between 10 and 20 mg/l; in Stanislaus county it was 23 mg/l and Sutter county it was 47 mg/l.

Maximum nitrate concentration in Shasta, Tehama, Yolo, Sacramento, San Joaquin, Madera, Fresno, Kings, and Tulare counties was between 15 and 100 mg/l; in Glenn, Butte, Colusa, and Stanislaus counties was between 100 and 200 mg/l; in Kern county was 315 mg/l; and in Sutter county it was 4,600 mg/l.

Arsenic:

Arsenic is regulated by the U.S. EPA at a primary drinking water quality standard of 0.05 mg/l. It can be toxic to both plants and animals. For irrigation use, the guidelines recommend that its concentration not exceed 1 mg/l. Although arsenic has not been found to be essential to animals, small amounts have been added to animal feed as a growth stimulant. The NAS recommends that arsenic concentration in water used for irrigation not exceed 0.2 mg/l.

Table A.2(f) contains summary statistics of arsenic concentrations in the sixteen counties. (Arsenic concentrations in Table A.2-F are in ug/l). Mean arsenic concentrations in all sixteen counties are less than the primary drinking water quality standards. Maximum arsenic concentrations were: less than 0.05 mg/l in Shasta, Tehama, Glenn, Colusa, Sutter, Yolo, and Madera counties; less than 0.05

mg/l in Sacramento county; between 50 and 200 mg/l in Butte, San Joaquin, Stanislaus, Merced, Fresno, Kings and Tulare counties; and less than 4,000 mg/l in Kern county.

Selenium:

Selenium is a trace element that is toxic to aquatic life and is found to be mutagenic to nesting waterfowl. Its toxicity to fish and wildlife is through bioaccumulation. Selenium was found to be responsible for mutations of migratory birds in the Kesterson National Wildlife Refuge. High selenium concentration in soils of the west side of the San Joaquin Valley have raised considerable concern because of their potential to leach from the soil by subsurface irrigation return flow into the groundwater and into receiving surface waters. Although selenium is currently regulated by Federal standards at a MCL of 10 ug/l, the State has recommended more stringent long term objectives at specific sites in the Kesterson Wildlife Refuge.

Table A.2(g) contains summary statistics of selenium concentrations in the sixteen counties. Mean selenium concentrations were below the detection limit in Shasta county; less than 10 ug/l in Tehama, Glenn, Butte, Colusa, Sutter, Sacramento, San Joaquin, Stanislaus, Madera, Tulare, and Kern counties; between 10 and 20 ug/l in Yolo and Kings counties; 28 ug/l in Merced county and 207 g/l in Fresno county.

Maximum selenium concentrations of 10 to 50 ug/l were found in Sutter, San Joaquin, Stanislaus, Tulare and Kern counties; between 50 and 200 ug/l were found in Yolo, Kings, and Merced counties; and 28,800 ug/l was found in Fresno county.

Dibromochloropropane (DBCP):

DBCP's use as a nematocide (soil fumigant) in agricultural applications was discontinued in 1979 because of the health hazard it poses and because of its high potential for groundwater contamination by virtue of its high mobility in the soil. DBCP has been detected in many groundwater wells in the San Joaquin Valley. Prior to 1986, DBCP was not regulated. In 1986, it was regulated at a MCL of 1 ug/l; however in 1989, a more stringent standard of 0.2 ug/l MCL was imposed.

Table A.2(h) contains summary statistics of DBCP concentrations in the sixteen counties. DBCP concentrations above the detection limit were found in San Joaquin, Stanislaus, Merced, Madera, Fresno, Tulare, and Kern counties. Mean selenium concentrations of 0.2 to 1 ug/l were found in Stanislaus and Madera counties; of 1 to 2 ug/l were found in San Joaquin, Merced, Tulare, and Kern counties; and of 2.04 ug/l was found in Fresno county.

TABLE A.2 (a)

CHLORIDE CONCENTRATION (mg/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	290	7	0.0	170	11	20
Tehama	561	0	1.0	141	21	26
Glenn	611	0	2.0	233	20	21
Butte	1139	0	0.3	340	14	31
Colusa	331	0	0.5	457	77	88
Sutter	390	0	0.8	921	65	129
Yolo	484	0	1.0	660	66	79
Sacramento	840	3	<1.0	1080	42	122
San Joaquin	3129	0	0.0	2760	79	165
Stanislaus	1071	0	0.0	2000	79	142
Merced	2495	0	2.0	25,280	1798	2120
Madera	218	0	2.0	1443	47	125
Fresno	1879	1	0.1	9200	389	1016
Kings	253	0	2.0	16,000	223	1215
Tulare	1424	1	1.0	632	34	64
Kern	3991	0	0.0	44,000	163	1175

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (b)

SODIUM CONCENTRATION (mg/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean2/	Standard Deviation2/
Shasta	89	0	2.67	131.00	17.32	19.85
Tehama	78	0	8.16	61.10	20.64	8.08
Glenn	118	0	13.00	78.00	36.17	16.37
Butte	561	0	0.61	106.00	14.08	10.86
Colusa	46	0	19.00	180.00	93.26	44.45
Sutter	21	0	15.00	77.00	33.78	19.35
Yolo	126	0	9.40	320.00	94.63	56.18
Sacramento	188	0	2.20	193.00	22.25	27.41
San Joaquin	1046	0	1.35	550.00	44.56	48.99
Stanislaus	822	0	1.70	400.00	52.18	44.37
Merced	196	0	5.50	2900.00	125.71	327.13
Madera	117	0	8.00	107.00	24.61	11.41
Fresno	891	0	2.80	17,000.00	155.86	957.58
Kings	100	0	5.10	29,000.00	653.17	3053.80
Tulare	646	0	5.00	321.00	27.29	24.81
Kern	888	0	.20	486.00	47.26	42.58

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (c)

SULFATE CONCENTRATION (mg/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	168	31	0.1	36	7	6
Tehama	236	12	0.0	60	12	10
Glenn	284	0	0.5	80	23	15
Butte	695	7	0.0	880	15	65
Colusa	175	0	0.0	590	42	69
Sutter	114	0	0.2	160	25	34
Yolo	229	1	0.0	370	51	56
Sacramento	340	89	0.0	70	9	10
San Joaquin	1342	0	0.0	1300	32	89
Stanislaus	920	38	<0.2	1600	56	142
Merced	2234	8	0.8	32,926	3450	3245
Madera	142	12	1.0	69	9	10
Fresno	1380	4	<0.5	37,000	1493	2804
Kings	148	1	0.8	65,000	1684	6675
Tulare	686	0	0.0	620	19	41
Kern	1699	1	0.0	15,000	289	989

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (d)

BORON CONCENTRATION (mg/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	28	0	0	460	98	132
Tehama	6	0	0	50	10	20
Glenn	28	0	0	1110	129	273
Butte	65	0	0	440	34	86
Colusa	11	0	0	380	115	160
Sutter	10	0	0	450	179	176
Yolo	96	0	0	4030	847	797
Sacramento	108	0	0	500	28	89
San Joaquin	579	2	0	2800	59	256
Stanislaus	473	3	0	3500	89	280
Merced	1745	0	0	39,000	12,051	8668
Madera	67	0	0	190	29	59
Fresno	625	0	0	130,000	1986	8387
Kings	90	0	0	39,000	4235	6506
Tulare	505	0	0	530	17	48
Kern	670	0	0	2080	56	206

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (e)

NITRATE (TOTAL NO_3) CONCENTRATION (mg/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	87	13	0.0	19.0	3.1	3.1
Tehama	187	2	0.2	50.0	10.8	8.1
Glenn	302	1	0.0	150.0	11.1	12.0
Butte	707	6	0.0	120.0	9.4	12.0
Colusa	179	10	0.0	120.0	9.2	13.2
Sutter	114	1	0.0	4600.0	47.2	432.3
Yolo	214	4	0.0	53.0	8.8	9.7
Sacramento	191	13	0.0	15.3	3.3	3.1
San Joaquin	110	130	0.0	93.0	8.1	11.9
Stanislaus	1002	10	0.0	130.0	23.3	14.6
Merced	166	2	0.0	100.0	15.0	13.5
Madera	121	5	<0.1	30.0	5.7	6.3
Fresno	834	11	0.0	63.6	15.5	10.4
Kings	88	10	0.0	22.5	1.9	4.0
Tulare	644	2	0.0	85.0	13.6	14.2
Kern	1065	16	0.0	315.0	12.0	16.4

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (f)

ARSENIC (TOTAL) CONCENTRATION (ug/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	87	76	<0.5	40	12	10
Tehama	79	61	0.0	29	9	7
Glenn	65	38	0.0	10	2	3
Butte	193	119	0.0	61	4	8
Colusa	44	34	0.0	16	6	5
Sutter	22	0	5.0	32	15	8
Yolo	124	88	0.0	40	7	7
Sacramento	187	160	0.0	50	11	13
San Joaquin	662	273	0.0	83	14	14
Stanislaus	781	608	0.0	68	8	9
Merced	1446	405	<1.0	100	5	6
Madera	77	65	<1.0	27	5	7
Fresno	723	321	0.0	100	18	34
Kings	138	9	0.0	170	35	42
Tulare	394	215	0.0	190	9	24
Kern	912	258	0.0	4000	43	272

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (g)

SELENIUM (TOTAL) CONCENTRATION (ug/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean 2/	Standard Deviation 2/
Shasta	81	81	<0.5	<20	-	-
Tehama	76	69	0.0	4	3	2
Glenn	55	34	0.0	4	0	1
Butte	186	128	0.0	7	1	1
Colusa	41	36	0.0	4	3	2
Sutter	21	14	<1.0	10	3	3
Yolo	131	65	<0.5	100	13	18
Sacramento	167	161	<0.5	4	3	1
San Joaquin	583	421	0.0	38	1	4
Stanislaus	766	720	0.0	24	4	5
Merced	2691	1462	<0.1	450	28	62
Madera	71	70	<1.0	6	6	-
Fresno	727	471	0.0	28,800	207	1836
Kings	137	79	0.0	170	10	26
Tulare	372	245	0.0	10	1	2
Kern	484	236	0.0	40	3	5

1/ Less than limit of detection
2/ Calculated for measured data only

TABLE A.2 (h)

DBCP CONCENTRATION (ug/l) SUMMARY STATISTICS FOR SIXTEEN COUNTIES

(Period of Record: 1971 to Present)

County	Number of Observations Total	1/	Minimum	Maximum	Mean2/	Standard Deviation2/
Shasta	-	-	-	-	-	-
Tehama	-	-	-	-	-	-
Glenn	-	-	-	-	-	-
Butte	17	17	<0.010	<0.010	-	-
Colusa	-	-	-	-	-	-
Sutter	2	2	<0.010	<0.100	-	-
Yolo	57	57	<0.010	<0.010	-	-
Sacramento	-	-	-	-	-	-
San Joaquin	600	347	<0.001	14.100	1.045	1.599
Stanislaus	578	387	<0.001	13.000	0.332	1.007
Merced	361	114	<0.001	19.000	1.485	3.268
Madera	74	63	<0.005	2.900	0.525	0.838
Fresno	1633	245	<0.001	31.800	2.036	3.565
Kings	12	12	<0.005	<0.010	-	-
Tulare	192	46	0.001	21.000	1.612	2.910
Kern	360	178	0.001	16.300	1.047	2.017

1/ Less than limit of detection
2/ Calculated for measured data only

Maximum DBCP concentrations in Madera county was 2.9 ug/l; in San Joaquin, Stanislaus, Merced, and Kern counties were between 10 and 20 ug/l; in Tulare county it was 21 ug/l; and in Fresno county it was 31.8 ug/l.

Inventory #3: Major Ions by Depth and by County

This inventory contains information on TDS, sodium, chloride, calcium, and sulfate for selective wells whose depth and perforation information are known. Depth information was used to categorize wells pumping from each of the three model layers. In of the Sacramento Valley, the depth of model layer 1 ranges from 0 to 350 ft, the depth of model layer 2 ranges from 80 to 750 ft, and the depth of model layer 3 ranges from 0 to 2,500 ft. In the San Joaquin Valley, the depth of layer 1 ranges from 0 to 700 ft, the depth of layer 2 ranges from 200 to 1,600 ft, and the depth of layer 3 ranges from 500 to 5,000 ft. Wells having multiple perforations are considered to be pumping from the lowest layer.

TDS:

Table A.3(a) summarizes TDS statistics by layers. Mean TDS concentration was generally below 500 mg/l in all layers of all counties, except in layer 1 of Merced and Kings counties. Mean TDS concentrations decreased from layer 1 to layer 2 in Shasta, Tehama, Glenn, Butte, Yolo, Sacramento, Stanislaus, Merced, and Kings counties, although the difference in Glenn and Sacramento counties is not significant. Information on Colusa, Sutter, and Fresno county was available for layer 1 only. Mean TDS concentration in San Joaquin, Tulare, and Kern county increased from layer 1 to layer 2, and in Kings county it also increased from layer 2 to layer 3. Mean TDS concentration decreased from layer 2 to layer 3 in Tulare county.

Chloride:

Table A.3(b) summarizes chloride statistics by layers. Mean chloride concentration was generally below 100 mg/l in all counties except Kern, Kings, and Tulare, where it ranged up to 150 mg/l. Mean chloride concentrations decrease with the depth in Shasta, Tehama, Glenn, Yolo, Sacramento, Stanislaus, Merced, and Kern counties. Mean chloride concentration increased from layer 1 to layer 2 in Butte, San Joaquin, Kings, and Tulare county, although the increase in Butte county may not be significant. In Kings county, mean chloride concentration increased from layer 2 to layer 3, whereas it decreased from layer 2 to layer 3 in Tulare county.

Sodium:

Table A.3(c) summarizes sodium statistics by layers. Sodium data with depth was only available for Stanislaus, Merced, Fresno, Tulare, and Kern counties. Mean sodium concentrations were between 20. and 100 mg/l. Mean sodium concentration increases with depth in Stanislaus and Kern counties, although the increase in Stanislaus county may not be significant. Mean sodium concentration in Merced county decreases with depth.

Calcium:

Table A.3(d) summarizes the calcium concentration statistics by layers for all counties. Calcium data by depth was available only for Stanislaus, Merced, Fresno, Tulare and Kern counties. Fresno and Tulare counties had calcium concentrations for 1 layer only. Mean calcium concentrations were generally below 100 mg/l in all counties. In Stanislaus, Merced and Kern counties, mean calcium concentration decreases with depth.

Sulfate:

Table A.3(e) summarizes the sulfate statistics for all counties by layers. Sulfate data was only available for Stanislaus, Merced, Fresno, Kings, Tulare, and Kern counties. Data for Fresno, and Tulare counties were available for 1 layer. Mean sulfate concentrations were generally below 100 mg/l, except in Kings county where they exceeded 250 mg/l. Mean sulfate concentration in Stanislaus and Kern counties increases with depth, and in Merced and Kings counties, it decreases with depth.

A.5 GROUNDWATER QUALITY PROBLEM AREAS IN CENTRAL VALLEY: A SUMMARY

TDS concentrations exceeding 1,500 mg/l were found in more than 15 % of Fresno county samples, in more than 25 % of Kings county samples and in 86 % of Merced county samples. TDS concentration in San Joaquin, Tulare, and Kern counties increases with depth from layer 1 to layer 2, and in Kings county, it increases from layer 2 to layer 3. Fogelman (1983) has plotted TDS concentrations in the Sacramento Valley.

Mean chloride concentrations exceeding 250 mg/l were found in Fresno county (398 mg/l) and in Merced county (1,798 mg/l). Maximum chloride concentrations between 1,000 and 3,000 mg/l were found in Sacramento, Madera, Stanislaus, and San Joaquin counties, and more than 9,000 mg/l were found in Fresno county (9,200 mg/l), Kings county (16,000 mg/l), Merced county (25,280 mg/l), and Kern county (44,000 mg/l). Chloride concentrations in San Joaquin, Kings and Tulare counties increased with depth from layer 1 to layer 2, and in Kings county, it increased from layer 2 to layer 3.

TABLE A.3 (a)

TOTAL DISSOLVED SOLIDS (mg/l) BY DEPTH CLASSIFICATION

(Period of Record: 1971-Present)

	LAYER 1				LAYER 2				LAYER 3			
	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation
Shasta	3	6	206	53	5[1/]	9	164	44	0	-	-	-
Tehama	4	9	300	194	12[1/]	20	214	88	0	-	-	-
Glenn	8	20	324	120	2[1/]	12	320	44	0	-	-	-
Butte	10	26	289	134	2	18	186	35	0	-	-	-
Colusa	0	-	-	-	7	18	454	249	0	-	-	-
Sutter	9	16	356	142	0	-	-	-	0	-	-	-
Yolo	2	3	460	115	2[1/]	2	420	113	0	-	-	-
Sacramento	7	8	224	58	1	2	219	2	0	-	-	-
San Joaquin	1	2	212	2	18[1/]	65	316	82	0	-	-	-
Stanislaus	16	80	454	221	5[1/]	26	440	230	0	-	-	-
Merced	2	3	634	10	1[1/]	1	275	-	0	-	-	-
Madera	0	-	-	-	0	-	-	-	0	-	-	-
Fresno	5	69	183	53	0	-	-	-	0	-	-	-
Kings	8	11	782	241	1	3	401	12	2[1/]	4	601	392
Tulare	2	2	221	177	5	7	427	89	2[1/]	2	203	26
Kern	7	29	266	102	19[1/]	41	485	305	0	-	-	-

[1/] Multiple Well Perforations

C-038512

TABLE A.3 (b)

SODIUM (Na, TOTAL) (mg/l) BY DEPTH CLASSIFICATION

(Period of Record: 1971-Present)

	LAYER 1				LAYER 2				LAYER 3			
	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation
Shasta	3	0	-	-	5[1/]	0	-	-	0	-	-	-
Tehama	4	0	-	-	12[1/]	0	-	-	0	-	-	-
Glenn	8	0	-	-	2[1/]	0	-	-	0	-	-	-
Butte	10	0	-	-	2	0	-	-	0	-	-	-
Colusa	0	-	-	-	7	0	-	-	0	-	-	-
Sutter	9	0	-	-	0	-	-	-	0	-	-	-
Yolo	2	0	-	-	2[1/]	0	-	-	0	-	-	-
Sacramento	7	0	-	-	1	-	-	-	0	-	-	-
San Joaquin	1	0	-	-	18[1/]	0	-	-	0	-	-	-
Stanislaus	16	84	58.69	35.46	5[1/]	31	56.22	44.59	0	-	-	-
Merced	2	6	58.17	27.27	1[1/]	1	42.30	-	0	-	-	-
Madera	0	-	-	-	0	-	-	-	0	-	-	-
Fresno	5	28	20.98	3.64	0	-	-	-	0	-	-	-
Kings	8	0	-	-	1	0	-	-	2[1/]	0	-	-
Tulare	2	0	-	-	5	4	39.75	1.50	2[1/]	0	-	-
Kern	7	9	27.78	4.89	19[1/]	6	66.53	33.63	0	-	-	-

[1/] Multiple Well Perforations

C-038513

C-038514

TABLE A.3 (c)

CHLORIDE (Cl, TOTAL) (mg/l) BY DEPTH CLASSIFICATION

(Period of Record: 1971-Present)

	LAYER 1				LAYER 2				LAYER 3			
	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation
Shasta	3	12	15	16	5 1/	20	9	9	0	-	-	-
Tehama	4	20	35	39	12 1/	53	18	26	0	-	-	-
Glenn	8	42	25	37	2 1/	16	14	4	0	-	-	-
Butte	10	54	11	14	2	20	12	2	0	-	-	-
Colusa	0	-	-	-	7	40	81	94	0	-	-	-
Sutter	9	69	25	21	0	-	-	-	0	-	-	-
Yolo	2	18	50	18	2 1/	18	27	7	0	-	-	-
Sacramento	7	63	18	17	1	5	8	4	0	-	-	-
San Joaquin	1	10	4	1	18 1/	227	67	78	0	-	-	-
Stanislaus	16	89	97	120	5 1/	33	46	66	0	-	-	-
Merced	2	6	99	46	1 1/	1	18	-	0	-	-	-
Madera	0	-	-	-	0	-	-	-	0	-	-	-
Fresno	5	72	20	8	0	-	-	-	0	-	-	-
Kings	8	17	84	74	1	4	102	3	2 1/	5	149	159
Tulare	2	3	5	3	5	11	32	11	2 1/	2	18	7
Kern	7	32	108	320	19 1/	41	58	51	0	-	-	-

1/ Multiple Well Perforations

C-038514

C-038515

TABLE A.3 (d)

CALCIUM (Ca, TOTAL) (mg/l) BY DEPTH CLASSIFICATION

(Period of Record: 1971-Present)

	LAYER 1				LAYER 2				LAYER 3			
	No. of Wells	No. of Obser - vations	Mean	Standard Deviation	No. of Wells	No. of Obser - vations	Mean	Standard Deviation	No. of Wells	No. of Obser - vations	Mean	Standard Deviation
Shasta	3	0	-	-	5 1/	0	-	-	0	-	-	-
Tehama	4	0	-	-	12 1/	0	-	-	0	-	-	-
Glenn	8	0	-	-	2 1/	0	-	-	0	-	-	-
Butte	10	0	-	-	2	0	-	-	0	-	-	-
Colusa	0	-	-	-	7	0	-	-	0	-	-	-
Sutter	9	0	-	-	0	-	-	-	0	-	-	-
Yolo	2	0	-	-	2 1/	0	-	-	0	-	-	-
Sacramento	7	0	-	-	1	0	-	-	0	-	-	-
San Joaquin	1	0	-	-	18 1/	0	-	-	0	-	-	-
Stanislaus	16	84	54.2	26.8	5 1/	31	53.5	21.2	0	-	-	-
Merced	2	6	70.7	27.6	1 1/	1	33.6	-	0	-	-	-
Madera	0	-	-	-	0	-	-	-	0	-	-	-
Fresno	5	28	20	8	0	-	-	-	0	-	-	-
Kings	8	17	84	74	1	4	102	3	2 1/	5	149	159
Tulare	2	3	5	3	5	11	32	11	2 1/	2	18	7
Kern	7	32	108	320	19 1/	41	58	51	0	-	-	-

1/ Multiple Well Perforations

C-038515

TABLE A.3 (e)

SULFATE (SO_4, TOTAL) (mg/l) BY DEPTH CLASSIFICATION

(Period of Record: 1971-Present)

	LAYER 1				LAYER 2				LAYER 3			
	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation	No. of Wells	No. of Obser-vations	Mean	Standard Deviation
Shasta	3	0	-	-	5[1/]	0	-	-	0	-	-	-
Tehama	4	0	-	-	12[1/]	0	-	-	0	-	-	-
Glenn	8	0	-	-	2[1/]	0	-	-	0	-	-	-
Butte	10	0	-	-	2	0	-	-	0	-	-	-
Colusa	0	-	-	-	7	0	-	-	0	-	-	-
Sutter	9	0	-	-	0	-	-	-	0	-	-	-
Yolo	2	0	-	-	2[1/]	0	-	-	0	-	-	-
Sacramento	7	0	-	-	1	0	-	-	0	-	-	-
San Joaquin	1	0	-	-	18[1/]	0	-	-	0	-	-	-
Stanislaus	16	82	28	50	5[1/]	31	63	86	0	-	-	-
Merced	2	6	99	42	1[1/]	1	35	-	0	-	-	-
Madera	0	-	-	-	0	-	-	-	0	-	-	-
Fresno	5	28	10	5	0	-	-	-	0	-	-	-
Kings	8	4	254	165	1	1	7	-	2[1/]	0	-	-
Tulare	2	0	-	-	5	6	56	20	2[1/]	0	-	-
Kern	7	10	36	7	19[1/]	7	52	23	0	-	-	-

1/ Multiple Well Perforations

Mean sodium concentrations exceeding 100 mg/l were found in Merced, Fresno and Kings counties, where maximum sodium concentrations were 2,900 mg/l, 17,000 mg/l and 29,000 mg/l, respectively. Sodium concentrations increased with depth in Kern county.

Mean sulfate concentrations exceeding 250 mg/l were found in Kern (289 mg/l), Fresno (1,493 mg/l), Kings (1,684 mg/l) and Merced (3,450 mg/l) counties, where maximum concentrations were 15,000 mg/l, 37,000 mg/l, 65,000 mg/l and 32,926 mg/l, respectively. Sulfate concentration in Stanislaus and Kern counties increases with depth.

Mean boron concentrations exceeding 0.5 mg/l were found in Yolo (0.85 mg/l), Fresno (1.99 mg/l), Kings (4.2 mg/l), and Merced (12.1 mg/l) counties, where maximum concentrations were 4.0 mg/l, 130.0 mg/l, 39.0 mg/l and 39.0 mg/l, respectively. Maximum concentrations in San Joaquin, Stanislaus and Kern counties were between 2.0 and 4.0 mg/l. Fogelman (1983) has plotted boron problem areas in the southwest Colusa county and much of Yolo county.

Mean nitrate concentrations exceeding 10 mg/l were in Tehama, Glenn, Merced, Fresno, Tulare, Kern, Stanislaus, and Sutter counties. Maximum nitrate concentrations exceeding 100 mg/l were found in Glenn, Butte, Colusa, Stanislaus, Kern (315 mg/l), and Sutter (4,600 mg/l) counties. Fogelman (1983) identified three nitrate problem areas in the Sacramento Valley groundwater: (i) portions of south Tehama county, northwest of Butte county, and northeast of Glen county; (ii) portions of south Butte county and northeast Sutter county; and (iii) around southwest of Butte county and northeast of Glenn county. Templin (1984: plate 7c) has mapped San Joaquin Valley areas where nitrate concentrations are greater than 10 and 20 mg/l. These areas include scattered spots in most of the San Joaquin Valley counties.

Maximum arsenic concentration is between 50 and 200 ug/l were in Butte, San Joaquin, Stanislaus, Merced, Fresno, Kings, and Tulare counties, and in Kern county it was 4,000 ug/l.

Mean selenium concentration greater than 10 ug/l were in Yolo, Kings, Merced (28 ug/l) and Fresno (207 ug/l) counties, where maximum concentrations were between 50 and 200 ug/l, except in Fresno county where the maximum concentration was 28,800 ug/l. Evenson and Neil (1986) have plotted selenium concentrations in groundwater of several parts of California, including the Central Valley.

Mean DBCP concentrations exceeding 0.2 ug/l were found in Stanislaus and Madera counties, and exceeding 1 ug/l in San Joaquin, Merced, Tulare, Kern, and Fresno counties. Maximum DBCP concentration in Madera county was 2.9 ug/l; in San Joaquin, Stanislaus, Merced, and Kern counties was between 10 and 20

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ug/l; in Tulare county 21 ug/l; and in Fresno county 31.8 ug/l. Templin (1984: plate 7d) has mapped groundwater DBCP problem areas in the San Joaquin Valley. Most serious DBCP contamination is noted in Fresno county (east and southeast of Fresno). Other contaminated areas include in Madera, Merced, Stanislaus, and San Joaquin counties.

Templin (1984: plate 9) has also identified other areas in the San Joaquin Valley which are of regional concern for possible contamination of groundwater. Those are southwestern San Joaquin county, western Stanislaus county, near Coalinga, around Raisin City and east of Fresno in Fresno county, eastern parts of Tulare county, north of Ripperdan in Madera county, between Cressey and Atwater in Merced, south of Hanford in Kings county and in the western, southern and south western parts of Kern county.

Additional sources of published information that would assist in future site specific groundwater quality investigations can be found in Bertoldi (1976), Evenson (1985), Fogelman (1977), Fogelman (1979), Gilliom and others (1989), Hull (1984), Izbicki (1984), Neil (1987), Page (1986), Pierce (1983), Shelton and Miller (1988), and Sorenson (1981).

Appendix B

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APPENDIX B

LAND SUBSIDENCE INVESTIGATIONS

B.1 INTRODUCTION

Land subsidence was not simulated by the Central Valley Groundwater Surface Water model, but was investigated separately. The land subsidence in the Central Valley as a result of excessive groundwater pumping has raised alarm and is discussed in this section. Groundwater overdraft stresses aquifer deposits and compacts aquifer material, causing land subsidence. Since the 1920's, excessive groundwater pumping for irrigation has resulted in widespread land subsidence. Its rate decreased in the 1950's and the late 1960's, after the Central Valley and State Water Projects began delivering surface water supplies for irrigation. Figure B.1 shows the major areas that have subsided by 1 ft or more since the 1920's due to groundwater pumping.

In the San Joaquin Valley, land subsidence is more widespread and more severe than in the Sacramento Valley. From 1920-1980, almost 5,200 square miles of the San Joaquin Valley's irrigated lands have registered at least 1 ft subsidence (Ireland, 1986). In parts of Western Fresno County subsidence levels as high as 30 ft have been measured.

In the Sacramento Valley, Yolo and Colusa Counties have subsided the most, with subsidence levels of up to 3.5 ft (Blodgett et al, 1989). Land subsidence in the Sacramento-San Joaquin Delta is not discussed in this section.

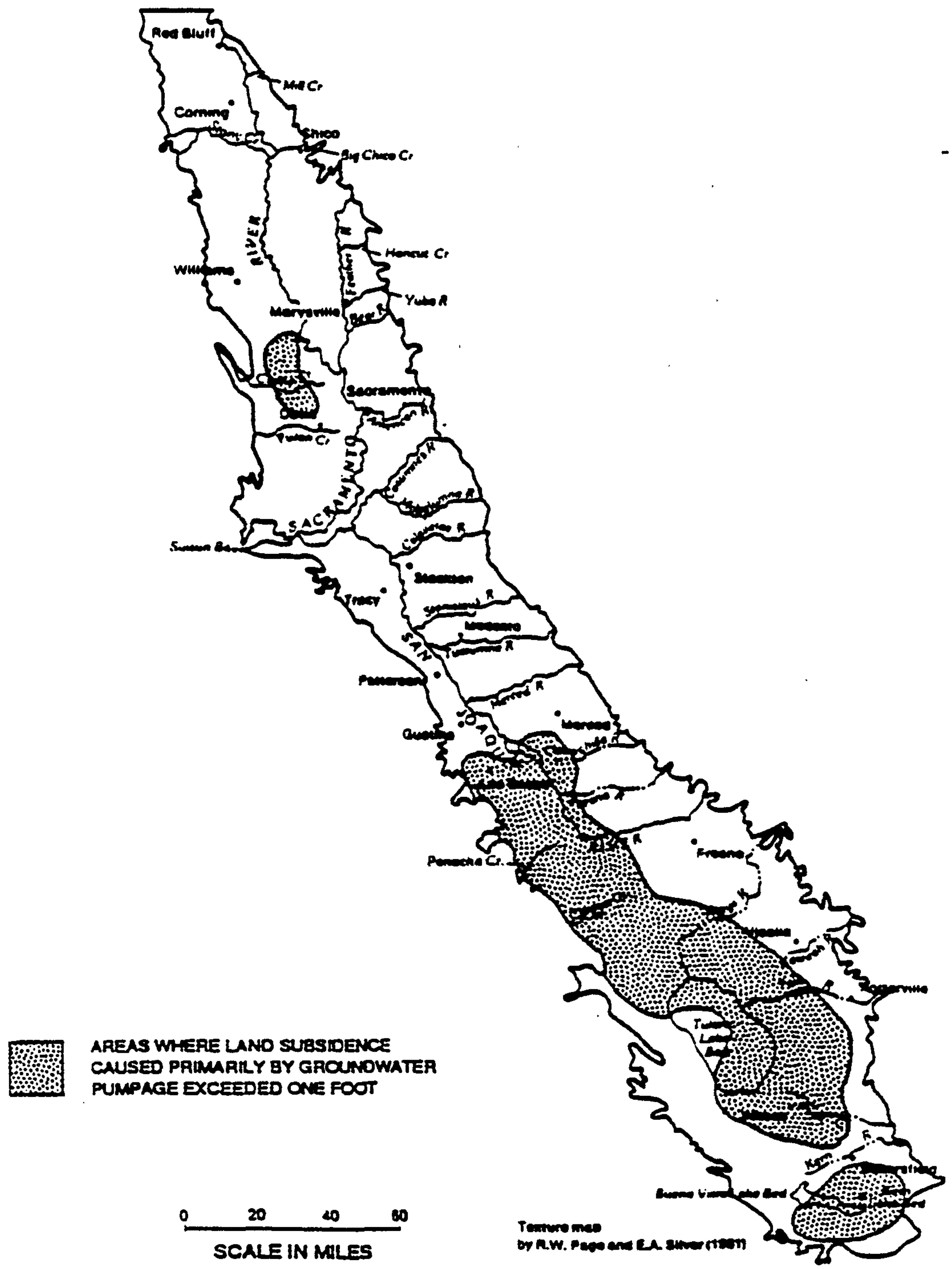
The objective of this discussion is to determine which Central Valley areas, if any, may suffer subsidence due to overpumping during dry years. Pumping rates from the 1976-77 drought year are used to approximate maximum dry year pumping.

<u>Summary of the findings</u>:

The areas most likely to subside as a result of overpumping are the existing subsidence areas:

* In the San Joaquin Valley -- the Los Banos-Kettleman City Area, the Tulare-Wasco Area, and the Arvin-Maricopa Area.
* In Sacramento Valley, the Davis-Zamora Area.

Other areas not currently exhibiting subsidence problems could nonetheless develop such problems in the future.



LOCATION OF THE PRINCIPAL CENTRAL VALLEY LAND SUBSIDENCE AREAS

(MODIFIED FROM WILLIAMSON AND PRUDIC 1984, FIGURE 1)

FIGURE B.1

In the San Joaquin Valley, a strong correlation exists between declining water levels and land compaction. However, a clear relationship between groundwater pumping and land subsidence has not been established for all the major Central Valley subsidence areas largely because of the variation in amounts of fine sediments in the soils, the type of clay materials present, the environment of deposition of sediments, and the changes in vertical hydraulic gradients in different areas (Williamson et al, 1985).

Information sources:

The information contained here is derived largely from the Central Valley subsidence investigations of the U.S. Geological Survey. Since 1956, USGS has been researching this problem in cooperation with the Department of Water Resources, and also under a federally funded research program on the mechanics of aquifer systems.

Land subsidence in the Sacramento Valley has not been investigated as extensively. A preliminary investigation was carried out by Lofgren and Ireland (1973). More recently, Blodgett et al (1989) measured land subsidence in the Sacramento Valley using Global Positioning System (GPS) survey data, but the findings of this survey are not yet available.

The five sections below describe:

1. the effects of groundwater pumping on land subsidence,
2. historical groundwater pumping patterns in the Central Valley,
3. the main San Joaquin Valley primary subsidence areas,
4. the Sacramento Valley subsidence areas, and
5. the factors influencing subsidence that can be used to predict future subsidence levels

B.2 THE EFFECTS OF GROUNDWATER PUMPING ON LAND SUBSIDENCE

Excessive groundwater pumping in both confined and unconfined aquifers can result in a decline in groundwater levels. In confined aquifers, groundwater pumping may also cause a decline in pressure head. In both cases, excessive groundwater pumping can cause land subsidence. The magnitude of land subsidence depends on the change in head as well as on the compaction characteristics and thickness of aquifer deposits (Poland and Evenson, 1966).

Declining water levels decrease the buoyant support of the aquifer material grains, and increase the gravitational stress on the underlying deposits. Also, a change in the water table or of the piezometric head, or both, can induce vertical hydraulic gradients across the confining bed and produce seepage stress (Lofgren, 1968). These two stresses are additive, and both increase the effective stress on the overlying deposits. The increase in effective stress is greater in the confined aquifer than in the unconfined aquifers, because of the induced additional seepage stresses, and causes greater aquifer compaction. Groundwater in the Sacramento Valley is pumped mostly under unconfined conditions, but in the San Joaquin Valley, it is pumped form both unconfined and confined aquifers.

The compaction characteristics of the aquifer deposits also influences land subsidence. Compaction of coarse sand and gravel is elastic, thus it is independent of time and is reversible. Conversely, compaction of clay deposits is generally inelastic because it rearranges the granular structure of clay material. Inelastic compaction is irreversible because it permanently decreases the volume of aquifer deposits (Lofgren, 1968). Most land subsidence in the San Joaquin Valley is from the permanent compaction of clayey deposits due to stresses induced by groundwater pumping since the mid-1920's.

B.3 HISTORICAL GROUNDWATER PUMPING PATTERNS

Beginning in the 1920's, farmers have pumped groundwater for irrigation in many parts of the Central Valley. As a result of heavy pumping, groundwater levels in parts of the San Joaquin Valley declined by more than 300 ft during the 1940's and 1950's. In the early 1950's, the Central Valley Project (CVP)--the Friant-Kern Canal and the Delta-Mendota Canal--began delivering surface supplies to the southern part of the San Joaquin Valley, replacing groundwater for irrigation. Users in other parts of the valley continued groundwater pumping which resulted in the decline of water levels and artesian heads. In 1968, the State Water Project (SWP) began importing additional surface supplies to farms located on the western and southern areas of the San Joaquin Valley. With farmers relying less on the groundwater, a dramatic reversal of artesian levels began. The 1976-1977 drought prompted excessive groundwater pumping in many parts of the valley, and water levels and pressure heads dropped considerably during this short period. Between 1978 and 1981, surface water deliveries were above normal and groundwater pumping decreased again. In many areas of the San Joaquin Valley, water levels and pressure heads recovered between 1978 and 1981 to pre-1976 levels. The severe water level declines in many areas of the San Joaquin Valley have resulted in very large subsidence areas that will be discussed in the following section.

Land subsidence in the Sacramento Valley is localized and is concentrated in areas of pumping overdraft. The areas of groundwater supply for irrigation have been much less in Sacramento Valley than in the San Joaquin Valley because of greater surface water availability. Consequently, the water level decline in most parts of the Sacramento Valley is much lower over the past 60 years of agricultural development. However, in a few localities, intensive groundwater pumping, prior to 1969, caused the water levels to decline between 40 and 110 ft (Lofgren and Ireland, 1973).

The major subsidence areas of the San Joaquin and Sacramento Valleys correspond to areas where water levels have declined significantly from historical overdraft conditions. Specific subsidence areas within the San Joaquin Valley and Sacramento Valleys are described below.

B.4 MAJOR SUBSIDENCE AREAS OF THE SAN JOAQUIN VALLEY

Figure B.2 shows the San Joaquin Valley subsidence areas and also the areas that are underlain by the Corcoran Clay member of the Tulare formation. Land subsidence in the San Joaquin Valley has occurred mostly in areas that are confined by the Corcoran Clay, where pressure changes due to groundwater pumping promotes greater compressive stress than in the unconfined zone (DWR, 1977).

Figure B.3 shows the locations of three major subsidence areas in the San Joaquin Valley that have been investigated by the USGS: the Los Banos-Kettleman City area, the Tulare-Wasco area, and the Arvin-Maricopa area (subsidence in the San Joaquin Valley has been measured by leveling of bench marks as well as by extensometers placed in wells). The California Aqueduct is located along the western side of the Los Banos-Kettleman City area and around the western and southern sides of the Arvin-Maricopa area. Subsidence along the California Aqueduct is also caused by hydrocompaction and is described in Ireland et al (1982) and Ireland (1986).

Figure B.3 also shows the locations of selected bench marks and observation wells whose compaction rates and water levels are described below.

<u>Los Banos-Kettleman City Area:</u>

Figure B.4 shows the location of the Los Banos-Kettleman City area covering about 2,600 square miles and its subsidence level contours plotted from 1926 through 1970. This area is the largest of the three subsidence areas in the San Joaquin Valley and extends from Merced County to Kings County, but is mostly located within the western Fresno County. The Los Banos-Kettleman City area also has the maximum subsidence levels recorded in the Central Valley. At bench mark S661, located 10 miles southwest of Mendota, a subsidence level of 29.6 ft was recorded in 1979 (Ireland et al, 1982). Water levels monitored at wells near the bench mark fluctuated by almost 300 ft between the 1950's and 1980. The compaction rate at bench mark S661 varied from a high of 1.7 ft/yr between 1954 and 1956 to a low of less than 0.1 ft/yr in 1981.

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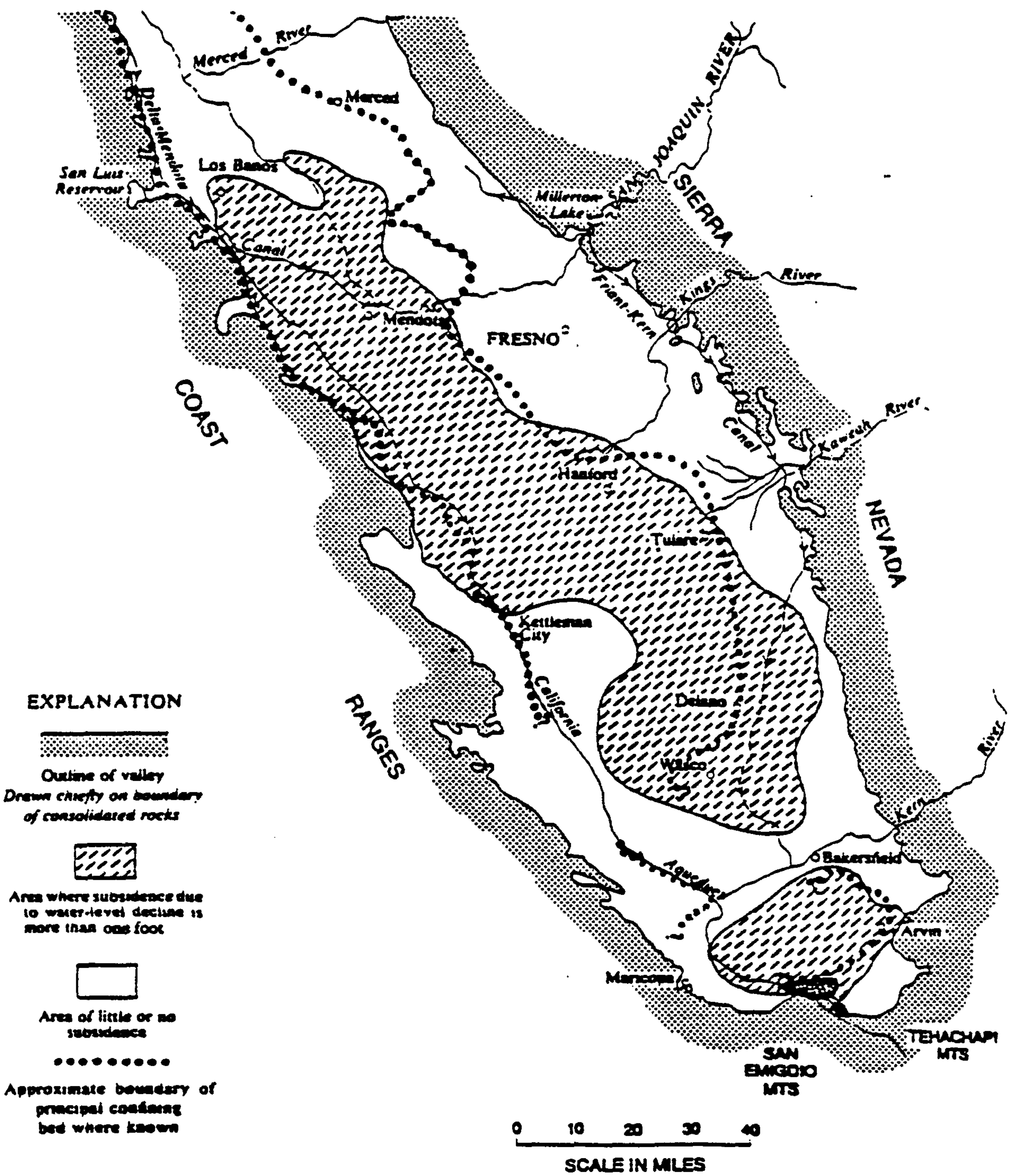
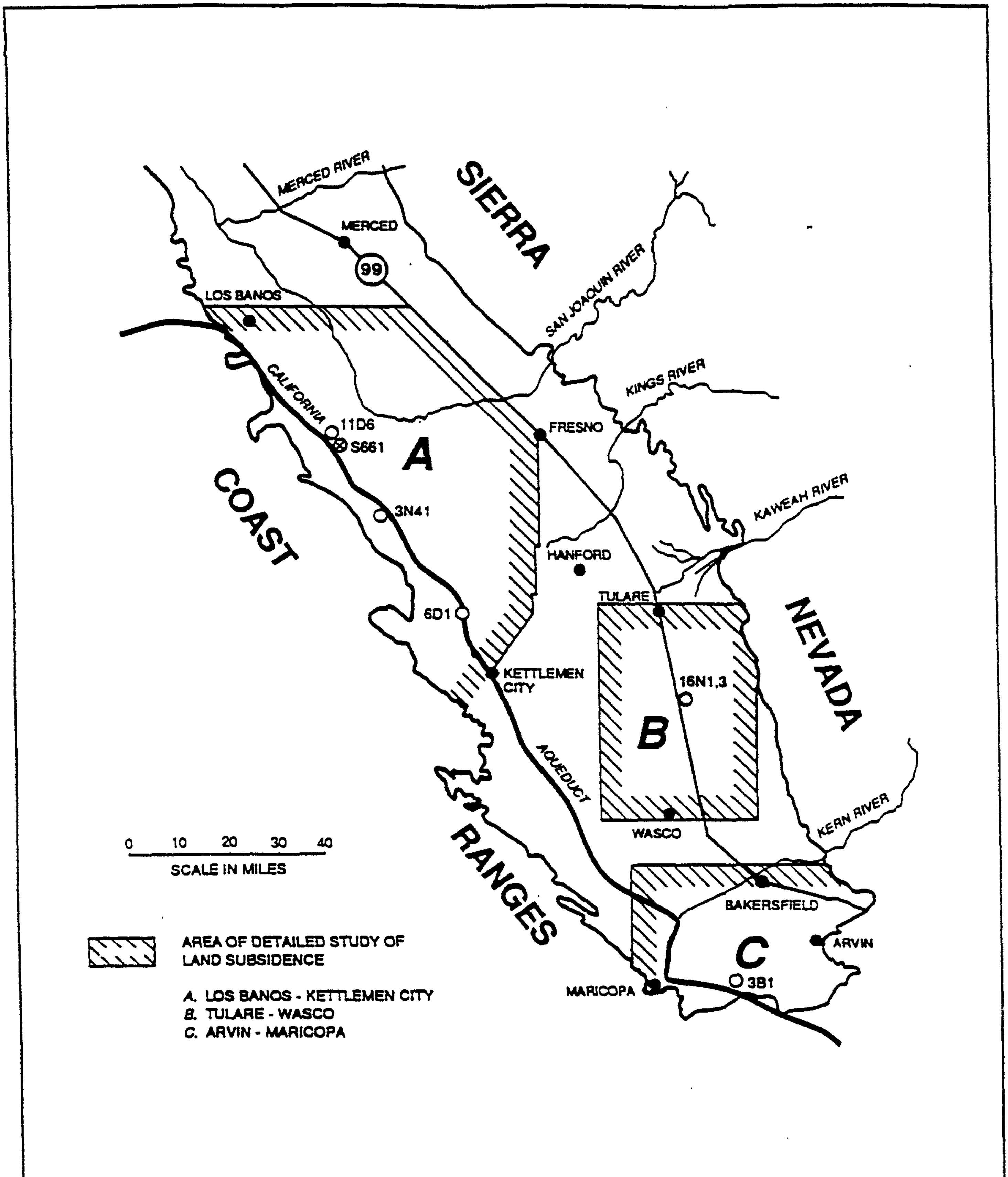


THE SAN JOAQUIN VALLEY SUBSIDENCE AREAS UNDERLAIN BY THE CORCORAN CLAY

(MODIFIED FROM POLAND, 1984, FIGURE 9.13.2)

FIGURE B.2

C-038525

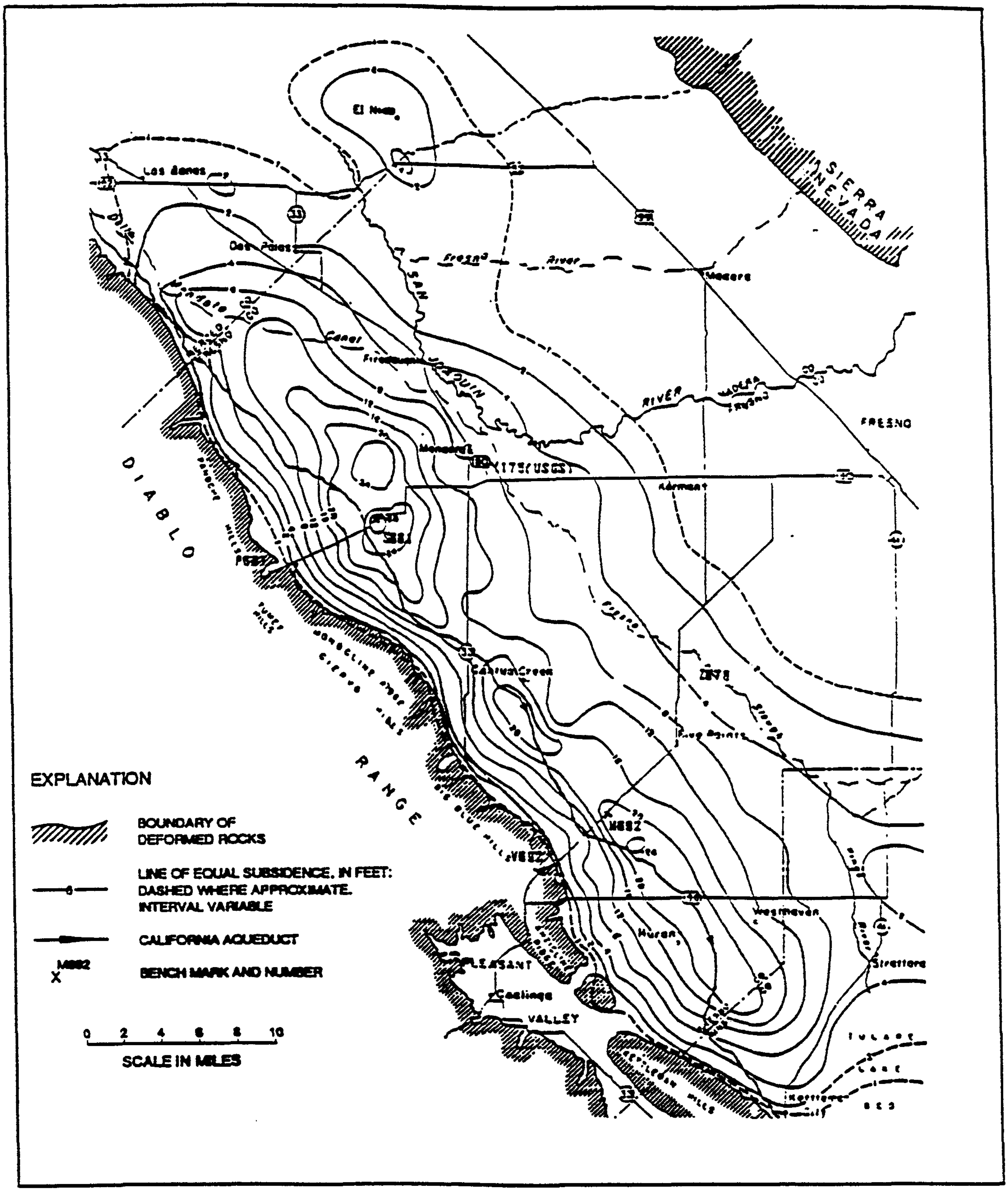


LOCATIONS OF THE PRINCIPAL SAN JOAQUIN VALLEY AREAS

(MODIFIED FROM IRELAND ET AL. 1984, FIGURE 32)

FIGURE B.3

C-038526



LAND SUBSIDENCE IN LOS BANOS - KETTLEMEN CITY AREA BETWEEN 1926 AND 1972

(MODIFIED FROM IRELAND ET AL. 1982, FIGURE 4)

FIGURE B.4

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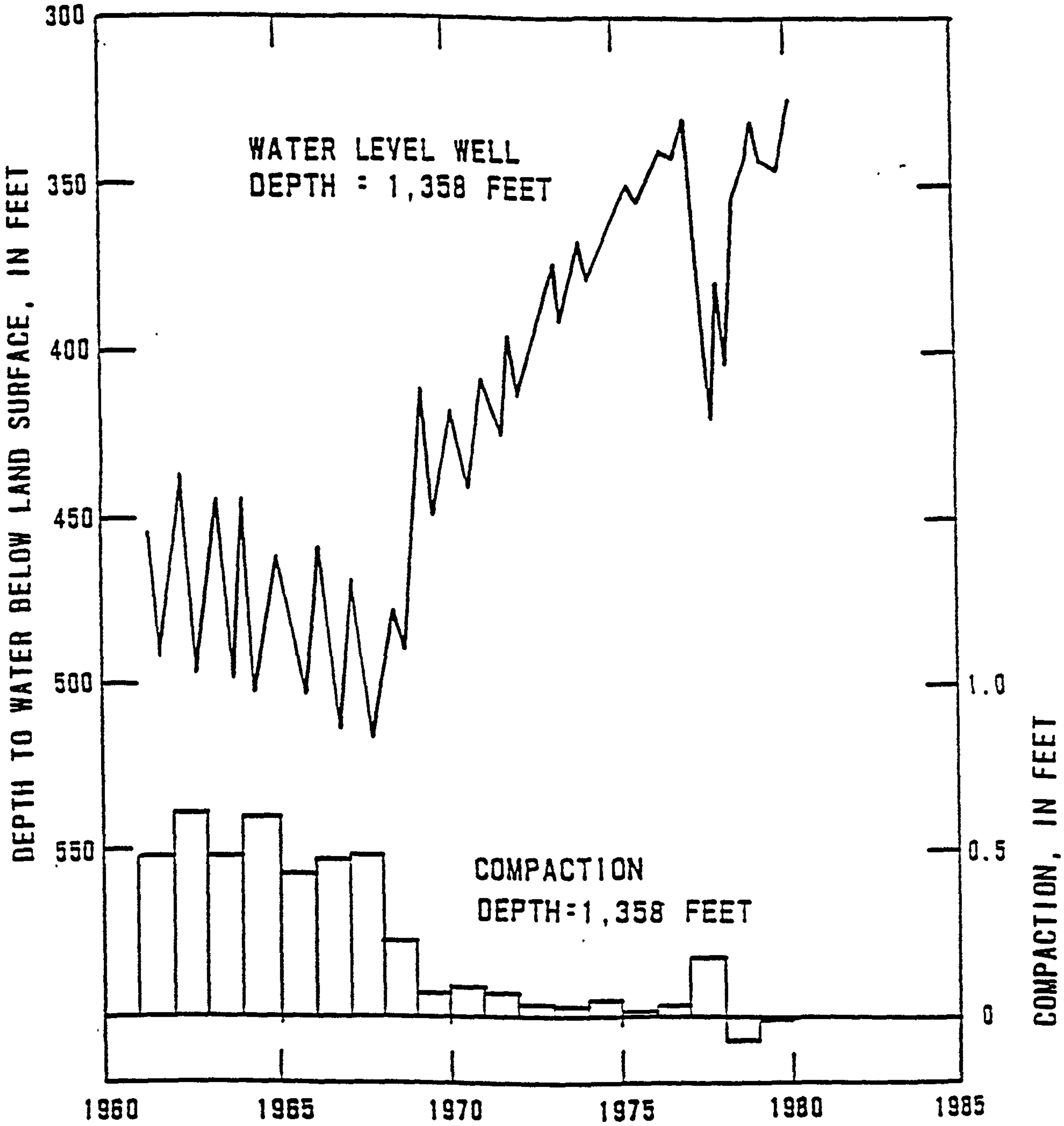
Prior to the late 1960's (when the SWP deliveries began), between 75 and 80 percent of the total groundwater supply for Los Banos-Kettleman City area was pumped from the confined aquifer (Bull and Miller, 1975). The Corcoran Clay confines the lower aquifer under most of the Los Banos-Kettleman City area, except in its southwestern part of the area. Figure B.4 shows three subareas--south and west of Mendota, south and west of Cantua Creek, and in the vicinity of Huron--where subsidence levels exceeded 20 ft in 1981. Groundwater level changes and compaction levels monitored at sites within the sub-areas are described below. Figure B.5 shows water levels and compaction monitored between 1960 and 1980 at Well 14/13-11D6 located southwest of Mendota. Between 1960 and 1967, water levels in the well declined and reached their lowest level in 1967. The compaction during the same period averaged above 0.5 ft/yr, with a high of almost 0.6 ft/yr during 1963 and 1965. As groundwater pumping decreased from 1968 and 1976, water levels recovered by about 175 ft and the corresponding compaction decreased to less than 0.1 ft/yr. During the 1977 drought year, the compaction increased to 0.18 ft/yr. In 1978 and 1979, an expansion of 0.07 ft/yr and 0.01 ft/yr was recorded.

Figure B.6 shows water levels and compaction monitored between 1961 and 1980 at Well 16/15-34N1 located near Cantua Creek. Between 1961 and 1967, the water levels decreased and reached their lowest point in 1967. The compaction rate between 1961 and 1967 averaged around 1.0 ft/yr. Since 1967, water levels recovered almost 260 ft. Between 1968 and 1976, the compaction rate decreased rapidly and was almost halted in 1976. During the 1976-1977 drought year, compaction increased to almost 0.45 ft/yr. In 1978, an expansion of about 0.03 ft/yr was recorded.

Figure B.7 shows water and compaction levels monitored between 1965 and 1980 at Well 20/18-6D1 located northeast of Huron. Between 1965 and 1967, water levels declined and reached their lowest in 1967, and the compaction rate during that period averaged about 0.25 ft/yr. Between 1968 and 1976, water level recovered almost 250 ft, and the corresponding compaction decreased and was reversed to an expansion of about 0.02 ft/yr in 1974. During the 1976 and 1977 drought year, water levels declined by about 250 ft, and the corresponding compaction of 0.2 ft/yr was recorded. Water level recovered by almost 200 ft between 1978 and 1980, and resulted in an expansion of 0.09 ft/yr in 1978 and a compaction of 0.02 ft/yr in 1979.

Tulare-Wasco Area:

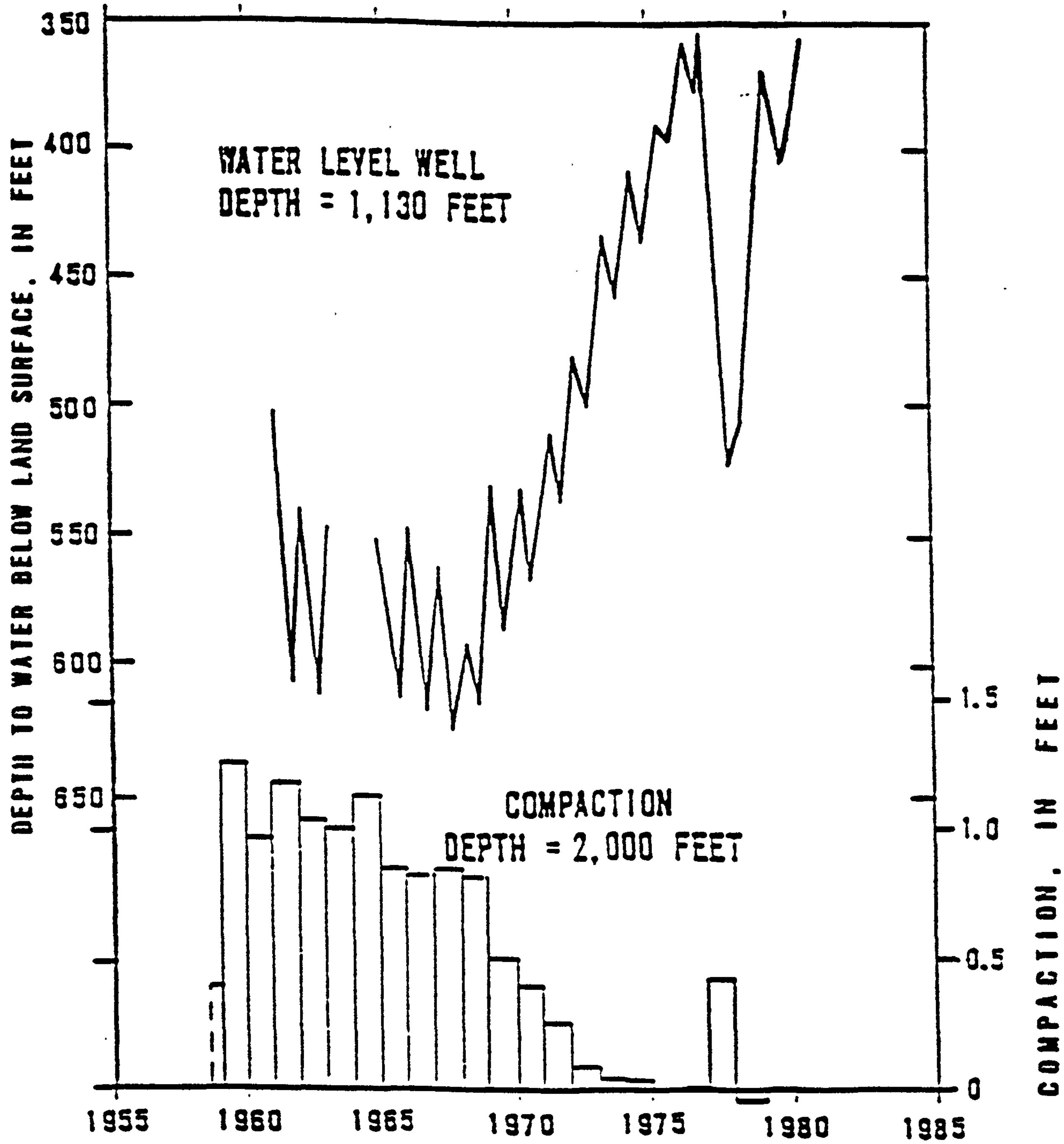
Figure B.8 shows the location of the Tulare-Wasco area and the subsidence level contours plotted for the 1926 through 1970 period. The Tulare-Wasco area is located between Fresno and Bakersfield, and resides mostly in the Tulare County. It covers an area of about 1,200 square miles. More than half of the Tulare-Wasco area, the area west of highway 99, is underlain by Corcoran Clay. The



WATER LEVELS AND COMPACTION MEASURED IN WELL 14/13 - 11D6
LOCATED SOUTHWEST OF MENDOTA

(MODIFIED FROM IRELAND ET AL. 1982, FIGURE 22)

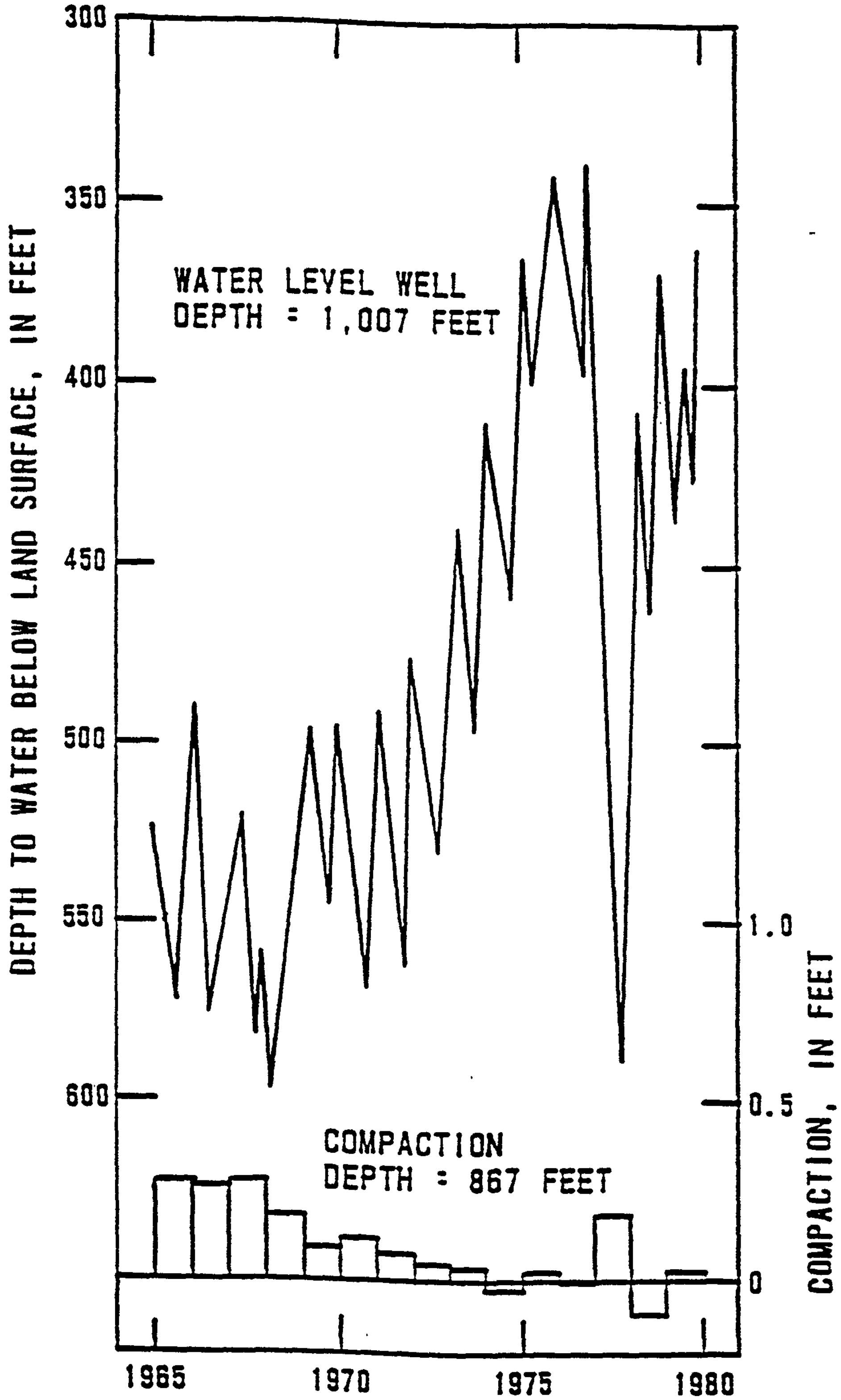
FIGURE B.5



WATER LEVEL IN WELL 16/15 - 34N4 AND COMPACTION MEASURED IN OBSERVATION WELL 16/15 - 34N1 NEAR CANTUA CREEK

(MODIFIED FROM LOFGREN, 1979, FIGURE 10)

FIGURE B.6



WATER LEVEL AND COMPACTION MEASURED IN WELL 20/18 - 6D1
NORTHEAST OF HURON

(MODIFIED FROM IRELAND ET AL. 1982, FIGURE 24)

FIGURE B.7

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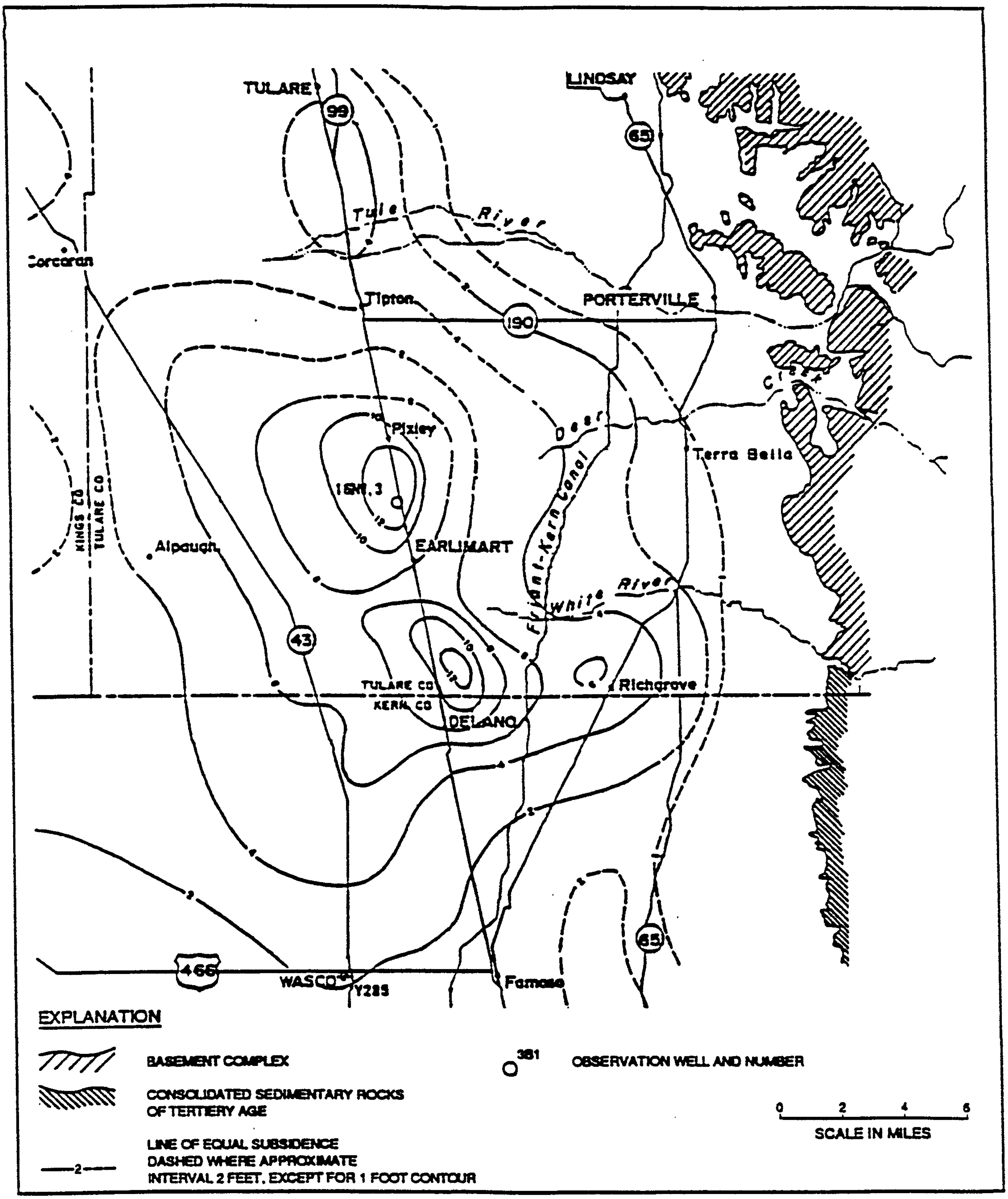


LAND SUBSIDENCE IN THE TULARE-WASCO AREA BETWEEN 1926 AND 1970

(MODIFIED FROM IRELAND ET AL. 1982, FIGURE 25)

FIGURE B.8

Tulare-Wasco area includes two areas where subsidence has exceeded 12 ft (Ireland et al, 1982).

Figure B.9 shows water levels measured at an observation Well 23/25-16N3 and compaction levels measured at a nearby Well 23/25-16N1, both in the vicinity of Pixley and monitored between 1959 and 1980. The artesian head in the observation well fluctuated more than 120 ft between the late 1950's and 1977. Maximum compaction rates of over 0.5 ft/yr were measured during 1960 and 1961. Compaction rates fluctuated from 0.35 ft/yr to less than 0.05 ft/yr between early 1960's and 1973 with seasonal low heads producing greater compaction. Compaction rates increased from less than 0.05 ft/yr in 1973 to almost 0.2 ft/yr in 1977, when the heads dropped to their lowest levels. In 1978, heads increased and the compaction was halted, and in 1979, it was less than 0.05 ft/yr.

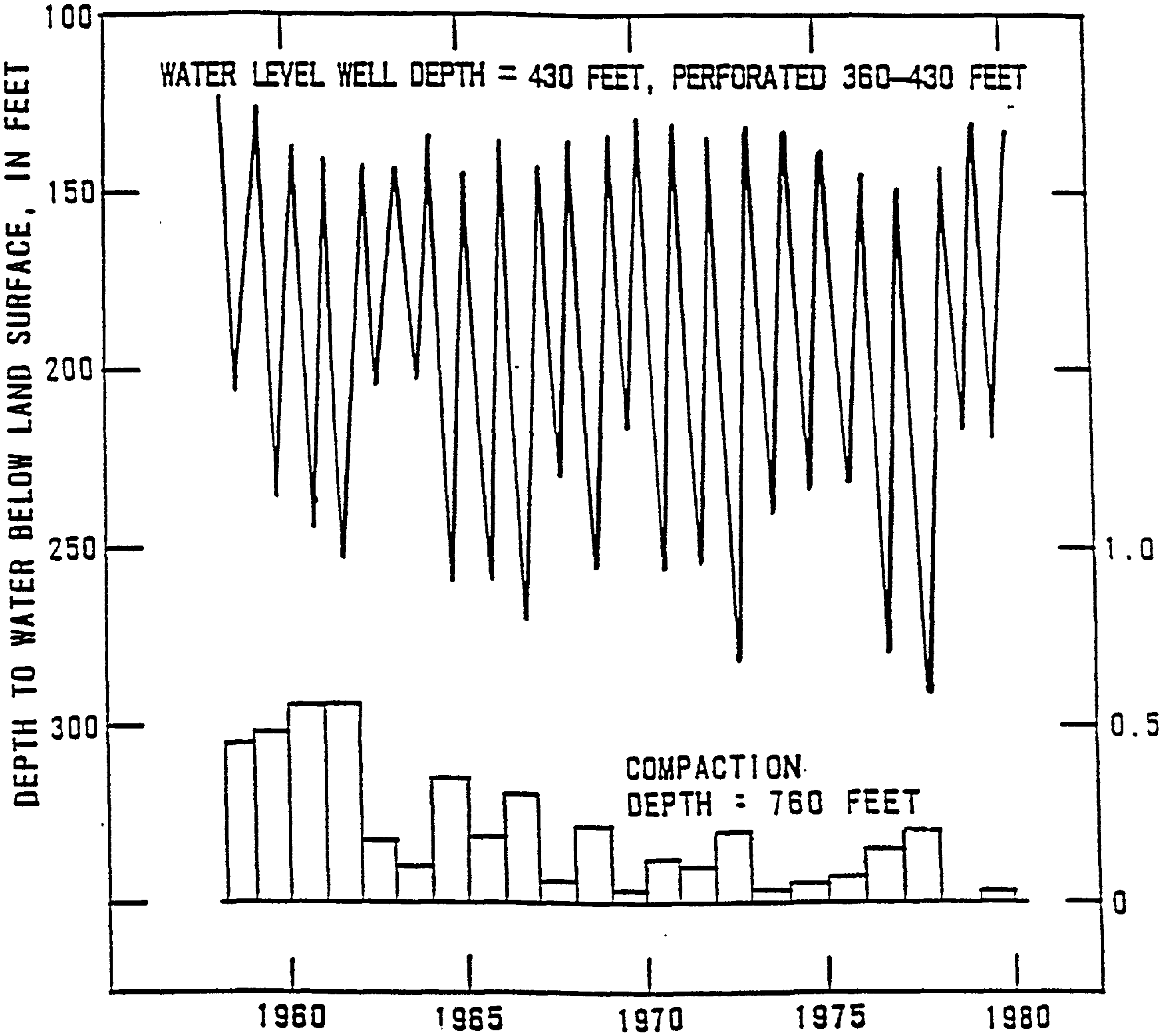
In areas where surface water was not available, wells were drilled between 1960's and 1970's, and an increase in groundwater pumping caused declines in water levels that resulted in increased land subsidence. Land subsidence at bench mark E757, located about 9 miles east of Delano, was 1.4 ft from 1964 to 1970 and 1.7 ft from 1970 to 1974 (Ireland et al, 1982).

Arvin-Maricopa Area:

Figure B.10 shows the location of the Arvin-Maricopa area and the subsidence level contours plotted for the 1926 through 1970 period. The Arvin-Maricopa area is located about 20 miles south of Bakersfield, mostly in Kern County. According to Lofgren (1975), the Arvin-Maricopa subsidence area includes 700 square miles of irrigated lands. The Arvin-Maricopa area is underlain by two confining beds, the A clay and the E clay. The E clay is more extensive of the two, even though its boundary northwest and west of the Arvin-Maricopa area is not known. Maximum land subsidence in the Arvin-Maricopa area exceed 9 ft. Land subsidence in parts of the Arvin-Maricopa area has also been caused by oil and gas withdrawal and hydrocompaction.

Figure B.11 shows water levels and compaction at Well 11N/21W-3B1 located 17 miles east of Maricopa which was monitored between 1963 and 1980. Artesian heads declined to their lowest in 1969. The compaction from 1964 and 1970 ranged between 0.3 ft/yr and 0.45 ft/yr. Artesian heads recovered by almost 150 ft between 1971 and 1976, and the corresponding compaction decreased and ranged from less than 0.1 ft/yr to 0.15 ft/yr. During the 1977 drought year, the head dropped about 90 ft, and caused compaction of 0.23 ft/yr in 1977. In 1978, water levels recovered and subsidence was reversed and an expansion of 0.02 ft/yr was measured, followed by 0.02 ft/yr of compaction in 1979.

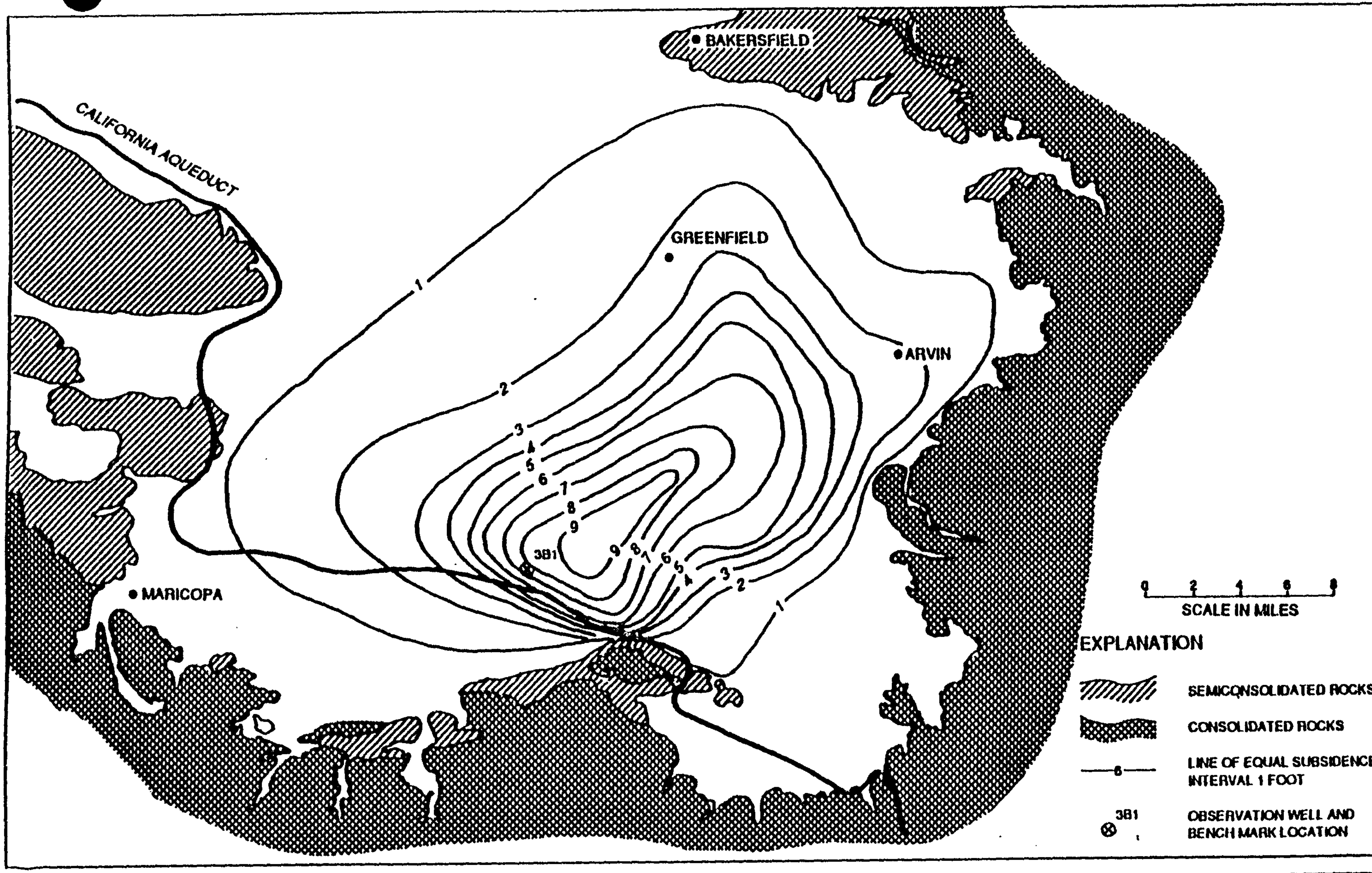
A more extensive list of compaction measurements recorded at 29 sites within the Los Banos-Kettleman City area, 11 sites within the Tulare-Wasco area, and 4 sites



WATER LEVEL IN OBSERVATION WELL 23/25 - 16N3 AND COMPACTION MEASURED IN WELL 23/25 - 16N1 NEAR PIXLEY

(MODIFIED FROM IRELAND ET AL. 1982, FIGURE 29)

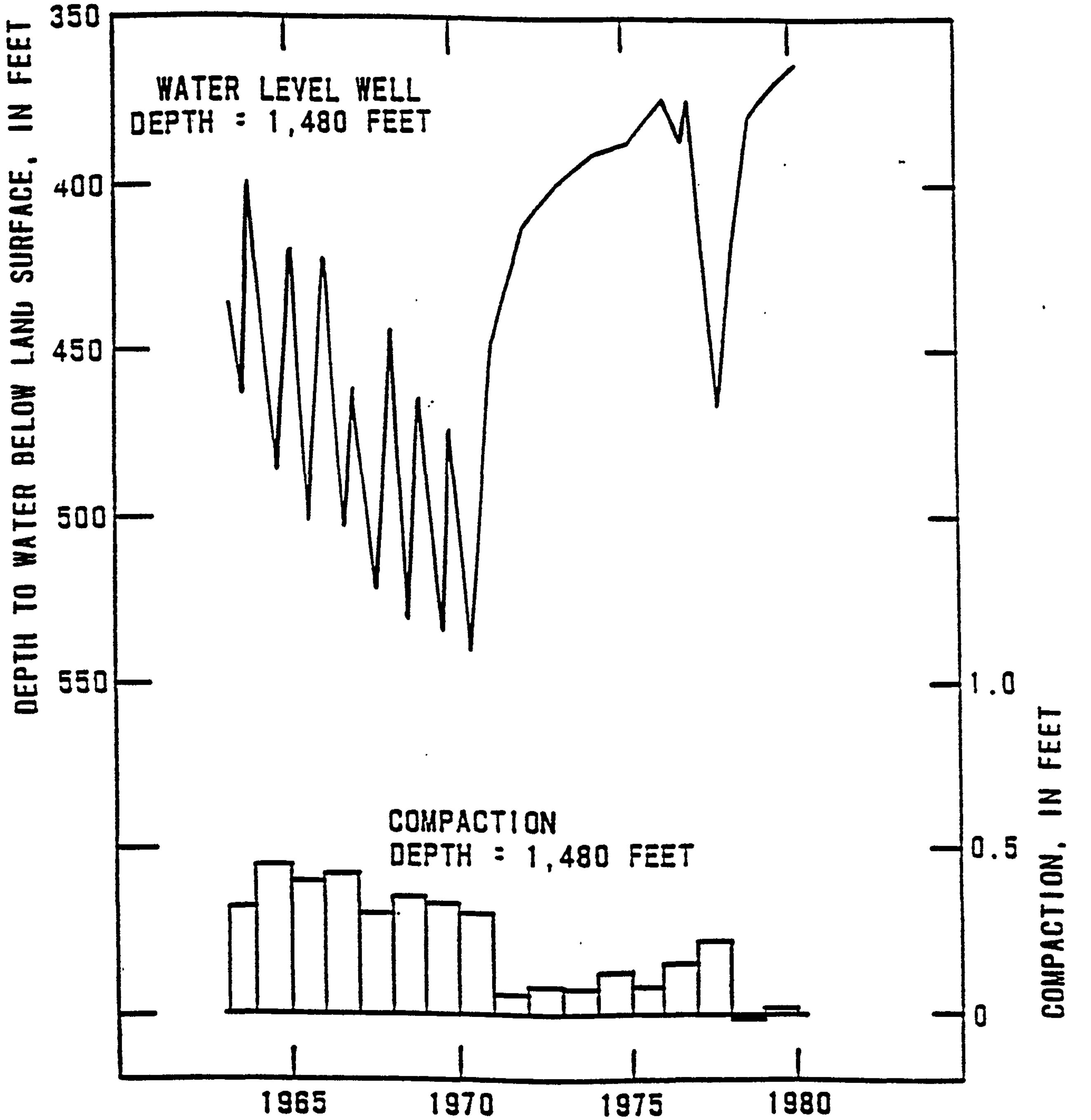
FIGURE B.9



LAND SUBSIDENCE IN THE ARVIN - MARICOPA AREA BETWEEN 1926 AND 1970

(MODIFIED FROM POLAND ET AL, 1975, FIGURE 30)

FIGURE B.10



WATER LEVEL AND COMPACTION MEASURED IN WELL 11N/21W - 3B1
EAST OF MARICOPA

(MODIFIED FROM POLAND ET AL. 1975, FIGURE 30)

FIGURE B.11

C—0 3 8 5 3 6

within the Arvin-Maricopa area is tabulated in Ireland (1986).

Figure B.12 shows the cumulative volume of land subsidence in the San Joaquin Valley as a whole, and also in the Los Banos-Kettleman City, the Tulare-Wasco, and the Arvin-Maricopa areas between 1925 and 1977. The cumulative subsidence volume in the Los Banos-Kettleman City area represents about 67 percent of the total subsidence volume of the San Joaquin Valley. The cumulative subsidence volume of the Tulare-Wasco area represents about 20 percent of the total San Joaquin Valley subsidence volume. The cumulative subsidence volume of the Arvin-Maricopa area was about 9 percent of the total San Joaquin Valley subsidence volume.

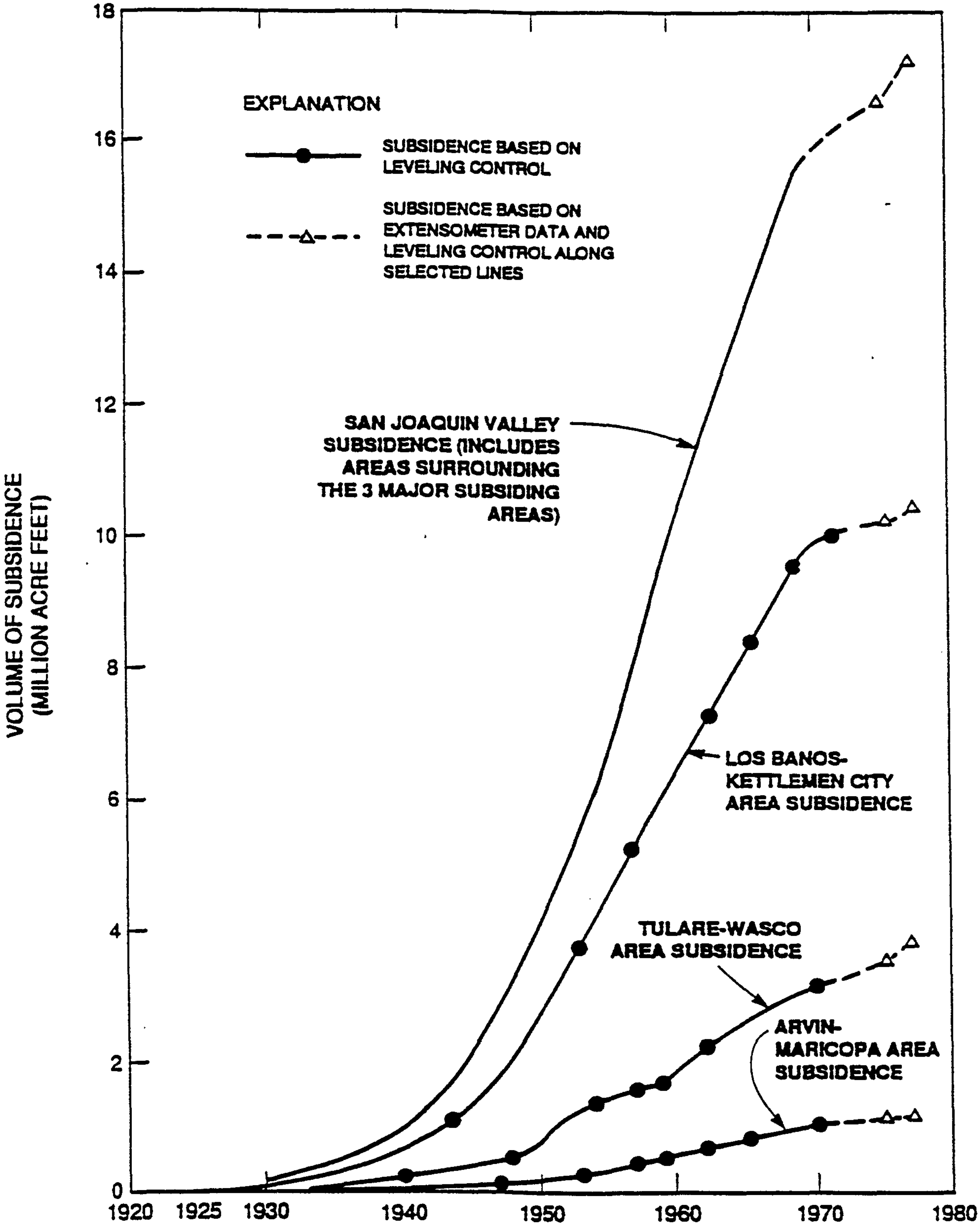
B.5 LAND SUBSIDENCE AREAS OF THE SACRAMENTO VALLEY

A preliminary investigation of land subsidence in the Sacramento Valley was conducted in 1973 by Lofgren and Ireland. It identified two main areas in the southwestern part of the valley where subsidence had exceeded 1 ft in 1973. In the areas east of Zamora and west of Arbuckle, subsidence levels of about 2 feet were measured by 1973 and were largely caused by pumping overdraft. Groundwater level declines of around 110 feet were measured between 1912/13 and 1969 near Arbuckle, with most of the declines occurring between 1950 and 1966. South of Zamora, groundwater level declines of between 20 and 30 feet were reported between 1912/13 and 1969, with most level declines occurring between 1945 and 1967. Subsidence east of Arbuckle may have been due to gas field withdrawals.

Although a recent investigation by Blodgett et al (1989) measured maximum subsidence levels of about 3.5 ft in parts of the Sacramento Valley by using GPS survey data, the findings of this survey have not been published. Consequently, the data presented below is based on available information from the 1973 preliminary investigation by the USGS. The 1973 subsidence levels were derived from leveling data.

Figure B.13 shows selected regional leveling network within Colusa and Yolo counties, between Zamora and Davis (profile A-B), Zamora and an area west of Zamora (profile A-C), Zamora and Knights Landing (profile A-D), and Williams and Zamora (profile F-A).

Figure B.14 shows leveling profile A-B between Zamora and Davis measured between 1935/42 and 1964. Subsidence levels range from 0.3 ft to 0.9 ft, the latter measured at bench mark K201 located 5 miles north of Davis. Figure B.15 shows leveling profile F-A between Williams and Zamora measured between 1949 and 1967. Subsidence level of almost 1.0 ft was measured at bench mark T200 located in Arbuckle. At bench mark A644 located in Zamora, maximum



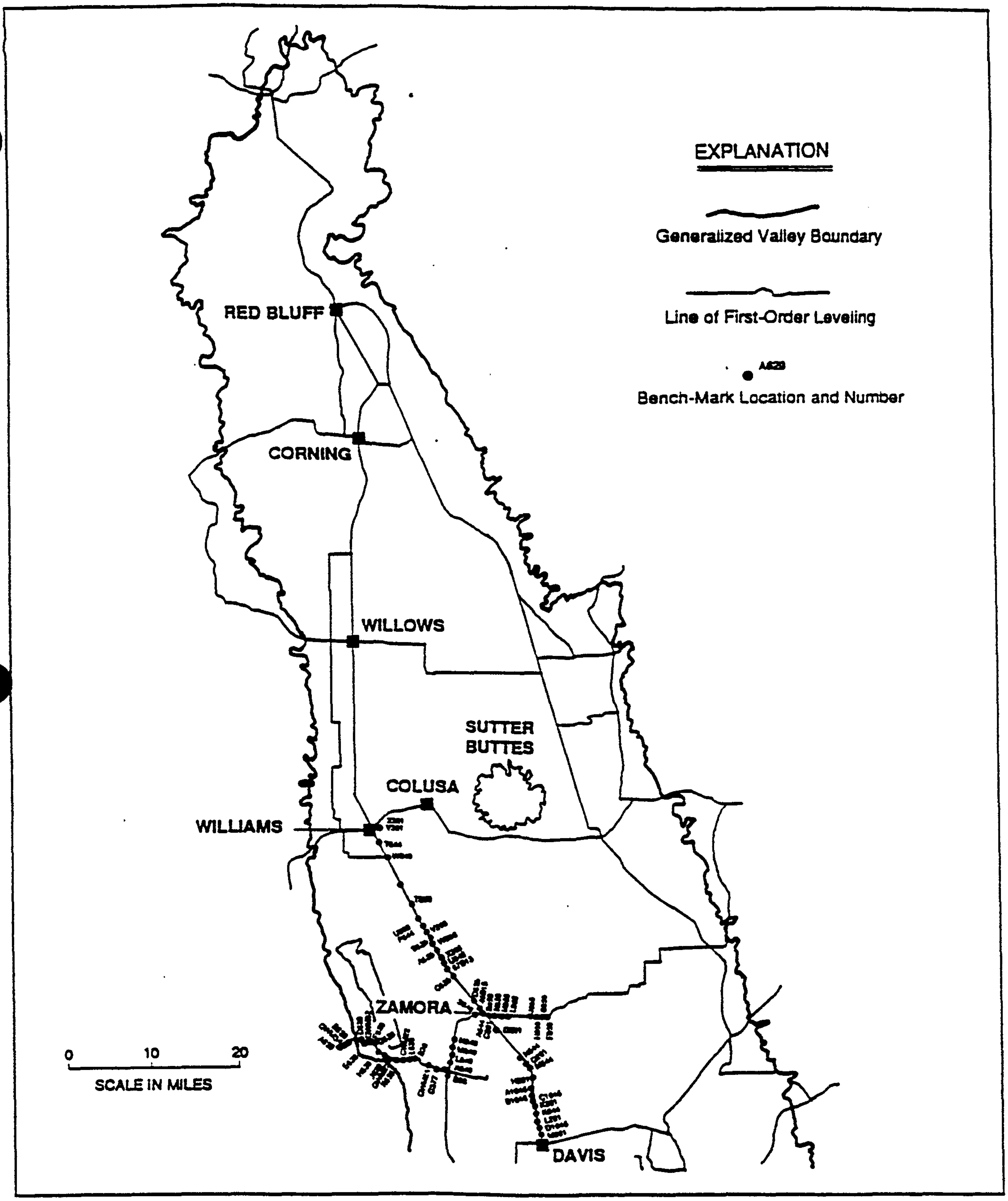
CUMULATIVE VOLUMES OF LAND SUBSIDENCE IN THE MAJOR SUBSIDING AREAS OF THE SAN JOAQUIN VALLEY BETWEEN 1925 AND 1977

(MODIFIED FROM WILLIAMSON ET AL. 1965, FIGURE 37)

FIGURE B.12

C-038538

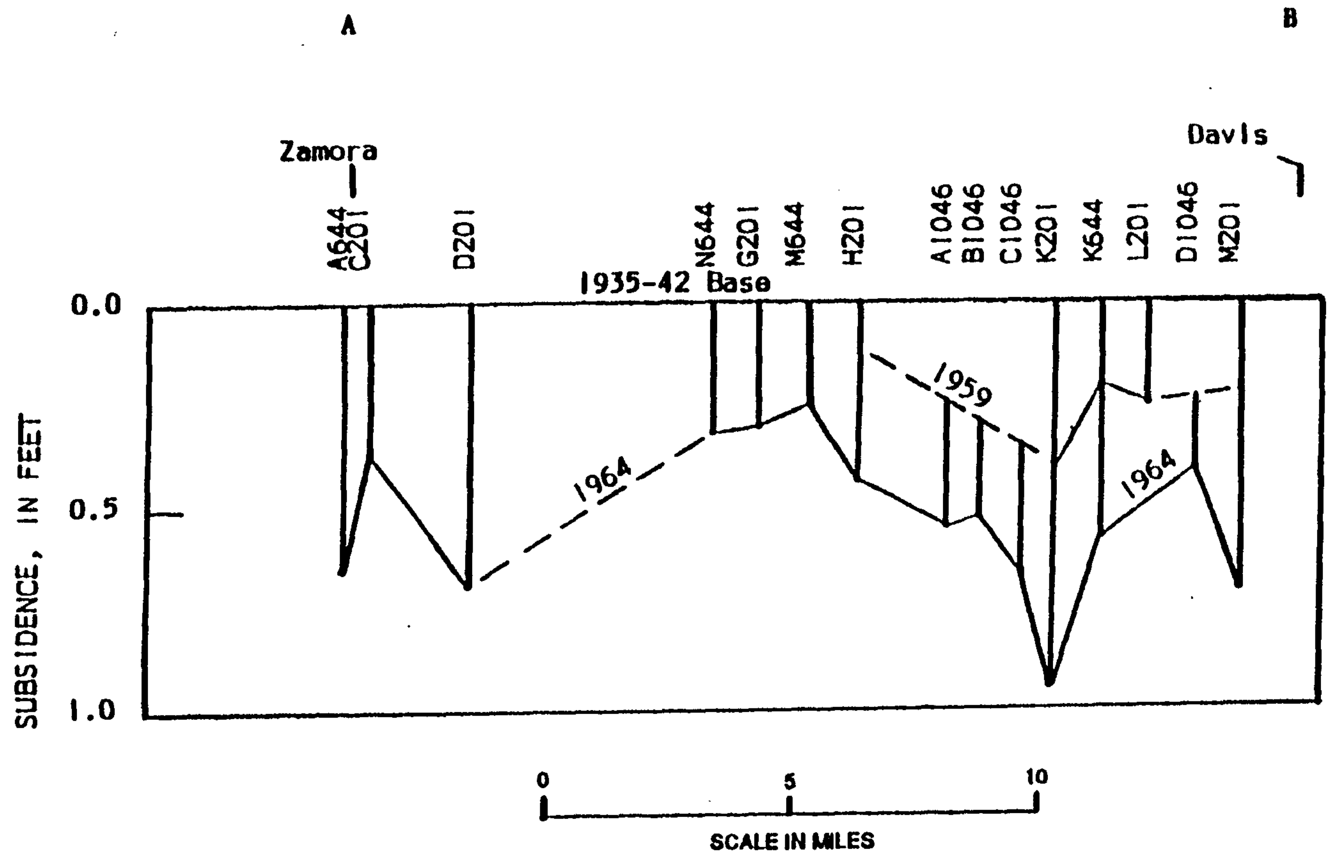
C-038538



REGIONAL LEVELING NETWORK FOR SACRAMENTO VALLEY

(MODIFIED FROM LOFGREN AND IRELAND (1973), FIGURE 2)

FIGURE B.13

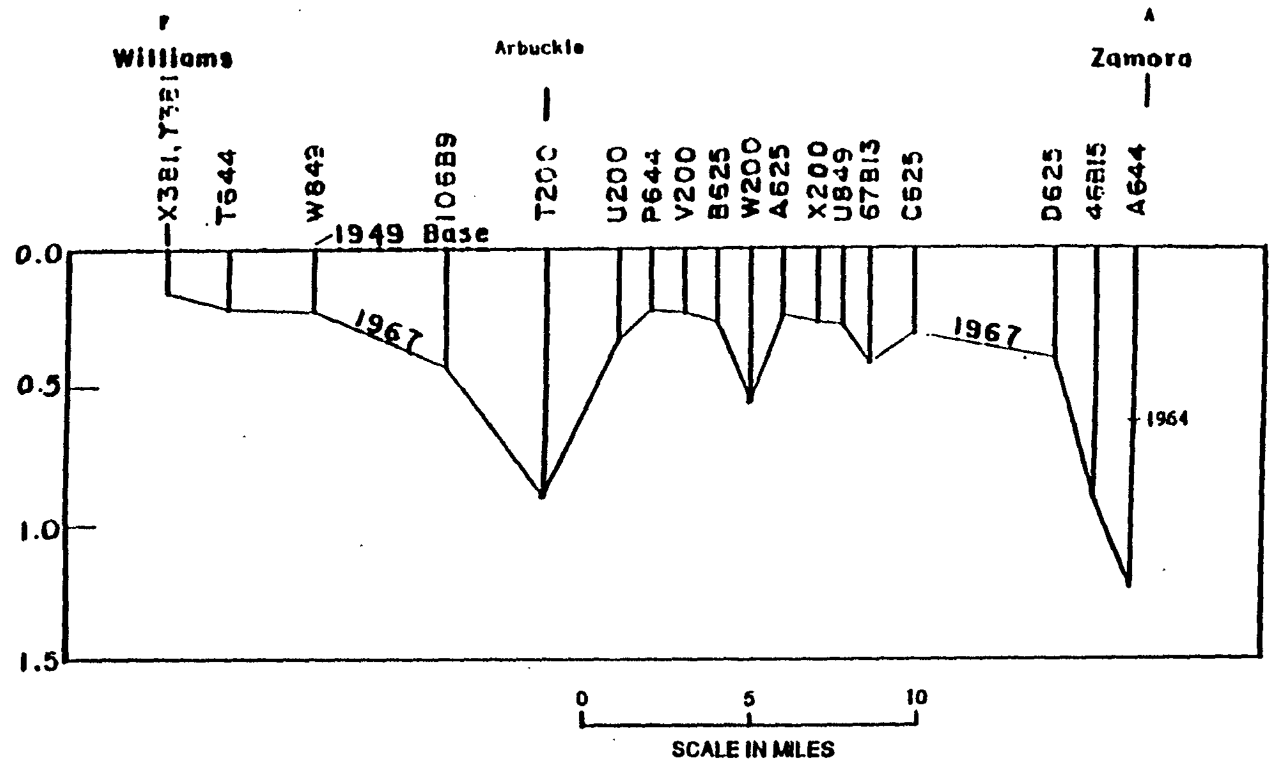


PROFILES OF APPARENT LAND SUBSIDENCE, A-B, 1935-42 TO 1964, FROM ZAMORA TO DAVIS

(MODIFIED FROM LOFGREN AND IRELAND (1973), FIGURE 5)

FIGURE B.14

C-038540



PROFILES OF APPARENT LAND SUBSIDENCE, F-A, 1949 TO 1967, FROM WILLIAMS TO ZAMORA

(MODIFIED FROM LOFGREN AND IRELAND (1973), FIGURE 7)

FIGURE B.15

subsidence level of 1.3 ft was measured. Subsidence levels decreased northwards between Arbuckle and Williams. Between Zamora and Arbuckle, subsidence levels decreased from bench mark A644 to bench mark C625 and thereafter, the pattern was uneven between bench marks C625 and T200 in Arbuckle.

Figure B.16 shows leveling profile A-C between Zamora and an area west of Zamora measured between 1949 and at various times in the 1960's. The area around Madison subsided by nearly 0.3 ft, and subsidence levels decreased westwards from Madison. The maximum subsidence was noted at bench mark A644 near Zamora, which subsided by about 0.7 ft between 1949 and 1964, and by an additional 0.6 ft between 1964 and 1967. Figure B.17 shows leveling profile A-D between Zamora and Knights Landing measured between 1949 and 1973. Maximum subsidence level of over 2.0 ft was measured at bench mark M589 located 2 miles east of Zamora. In general, subsidence levels east of Zamora were higher than those measured west of Zamora. Subsidence levels decreased eastwards from bench mark M589. In areas east of Corning and east of Willows, between 1949 and 1967, measurements at most bench marks indicated an elevation of land surface.

B.6 FACTORS AFFECTING CENTRAL VALLEY LAND SUBSIDENCE

Information about pumping alone is insufficient to predict the degree of subsidence in all the major subsidence areas of the Central Valley. Although a strong correlation exists between land compaction and water level declines, a clear relationship between groundwater pumping and land subsidence has not been established for all the areas discussed earlier.

The most important factor for predicting future subsidence levels is the subsidence to water level decline ratio (Lofgren, 1968), where water levels in the main aquifer were lowered below the historic minimum levels. Table B.1 lists the subsidence to water level ratios estimated for the San Joaquin Valley subsidence area to be: (a) 0.01-0.08 ft/ft for the Los Banos-Kettleman City area, (b) 0.01-0.06 ft/ft for the Tulare-Wasco area, and (c) 0.01-0.05 ft/ft for the Arvin-Maricopa area. There is insufficient data for the Davis-Zamora area to establish such a ratio.

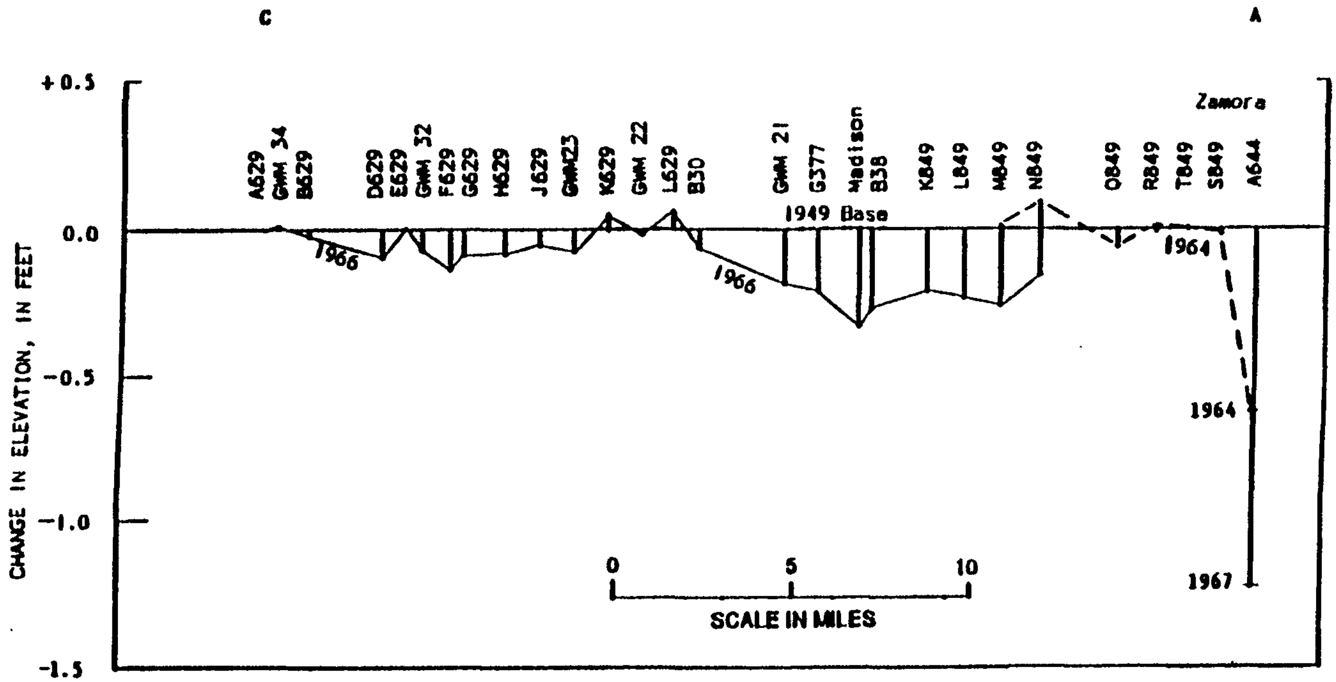
In the Los Banos-Kettleman City area, the subsidence to water level decline ratio can be interpreted to mean that water level declines of between 12 to 100 ft below historic minimum levels would cause subsidence of 1 ft. Similarly, for the Tulare-Wasco area and the Arvin-Maricopa area, water level declines of between 15 to 100 ft and 20 to 100 ft respectively, below their historic minimum levels would cause subsidence of 1 ft.

Figure B.18 shows a strong correlation between pumpage and volume of subsidence in the Los Banos-Kettleman City area. It indicates that about one third

TABLE B.1

SUBSIDENCE TO WATER LEVEL DECLINE RATIOS FOR THE MAIN CENTRAL VALLEY SUBSIDENCE AREAS

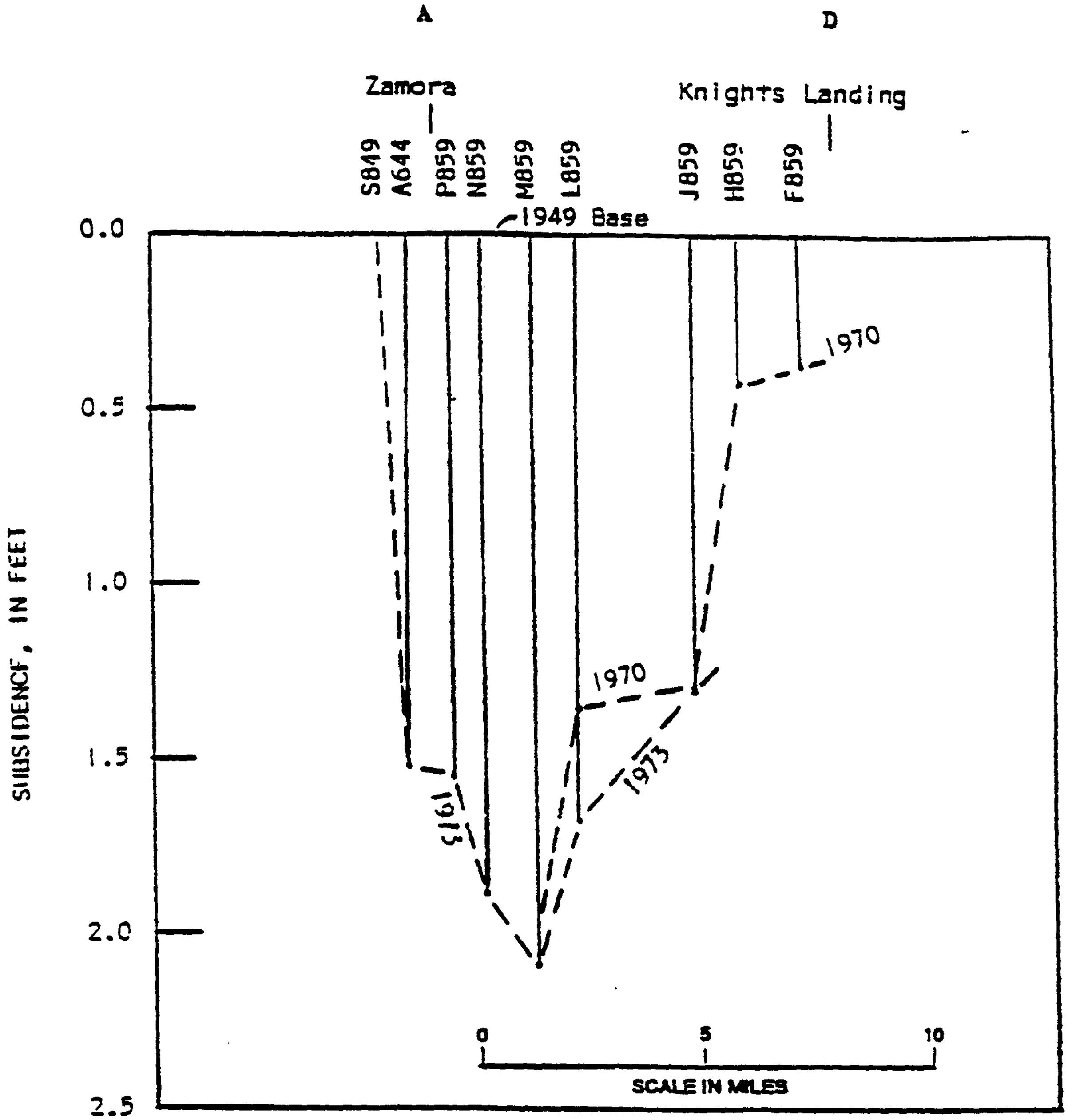
Subsidence Areas	Subsidence to Water Level Decline Ratio
Los Banos - Kettleman Area	0.01 -0.08 ft/ft
Tulare - Wasco Area	0.01 -0.06 ft/ft
Arvin - Maricopa Area	0.01 -0.05 ft/ft
Davis - Zamora Area	-



PROFILES OF APPARENT LAND-SURFACE CHANGE, C-A, 1949 TO 1964 AND 1966, FROM 28 MILES SOUTHWEST OF ZAMORA TO ZAMORA

(MODIFIED FROM LOFGREN AND IRELAND (1973), FIGURE 6)

FIGURE B.16



PROFILES OF APPARENT LAND SUBSIDENCE, A-D, 1949 TO 1970 AND 1973, FROM ZAMORA TO KNIGHTS LANDING

(MODIFIED FROM LOFGREN AND IRELAND (1973), FIGURE 12)

FIGURE B.17

of the water pumped from the Los Banos-Kettleman City area was derived from the compaction of fine clay beds in the confined aquifer (Poland, 1986). In the Tulare-Wasco and the Arvin-Maricopa areas, a direct relationship between pumpage and volume of subsidence is not as pronounced (Williamson et al, 1985), and data is insufficient to make such a comparison for the Davis-Zamora area.

Table B.2 shows the relationship between total pumpage estimated between 1961 and 1977, and the percentage of the pumpage released from the compaction of fine sediments from the confined aquifer in the three San Joaquin Valley subsidence areas and the unconfined aquifer in the Davis-Zamora area. Table B.3 shows that 35 percent of the total water pumped in the Los banos-Kettleman City area was released from the compaction of fine sediments from the confined aquifer. In contrast, only 11 percent of the total water pumped from the Tulare-Wasco area and 4 percent of the total water pumped from the Arvin-Maricopa area was water released from the compaction of fine sediments from the lower aquifer. In the Davis-Zamora area, 9 percent of the total pumpage came from the compaction of sediments. Williamson et al (1985) explained the wide variation as being related to the varying amounts of fine sediments, the types of clay minerals present, the environment of deposition of sediments, and the changes in vertical hydraulic gradients in different areas.

Table B.3 shows a similar relationship as in Table B.1, but for only the 1976-1977 drought years. A comparison of Table B.2 numbers with that of Table B.1 for the Los Banos-Kettleman City and the Arvin-Maricopa areas, indicates that proportionally less water was released from the compaction of sediments during the 1976-77 drought than during the 1961-1977 period, suggesting that a part of the 1976-77 compaction may have been elastic. A similar comparison for the Tulare-Wasco and the Davis-Zamora area shows the opposite, indicating that proportionally more inelastic compaction may have occurred in these two areas during the 1976-1977 drought than during the entire 1961-1977 period. The above comparisons indicate that the past stress history of the aquifer deposits influences the magnitude of current subsidence in these areas. It suggests that the 1976-77 pumping may not have induced stresses exceeding the Los Banos-Kettleman City and the Arvin-Maricopa area's preconsolidation stress limits, although this may not be true for local spots within the areas. A preconsolidated deposit cannot be compacted further until the applied stress exceeds the historic preconsolidated stress levels. This is an important concept for managing the groundwater resources of the Central Valley for cyclic storage.

Even though land subsidence had slowed down in many areas of the San Joaquin Valley by 1981, identifying future areas of land subsidence is important for the proper management of the Central Valley groundwater resources for conjunctive use. Excessive pumpage during the 1976-77 drought years reversed the 1969-1976 trend in water level recovery and caused additional compaction in many areas.

TABLE B.2

ESTIMATED PUMPAGE AND PERCENT OF PUMPAGE FROM COMPACTION OF LOWER AQUIFER FROM 1976-77 FOR THE MAJOR CENTRAL VALLEY SUBSIDENCE AREAS

Major Subsidence Area	Estimated Total Pumpage from Lower Pumped Zone (Million acre-ft.)	Estimated Volume of Subsidence (Million acre-ft.)	Estimated Percentage of Pumpage from Compaction
Los Banos - Kettleman Area	1.0	0.23	23
Tulare - Wasco Area	2.2	0.31	14
Arvin - Maricopa Area	1.4	0.04	3
Davis - Zamora Area	0.46	0.06	12

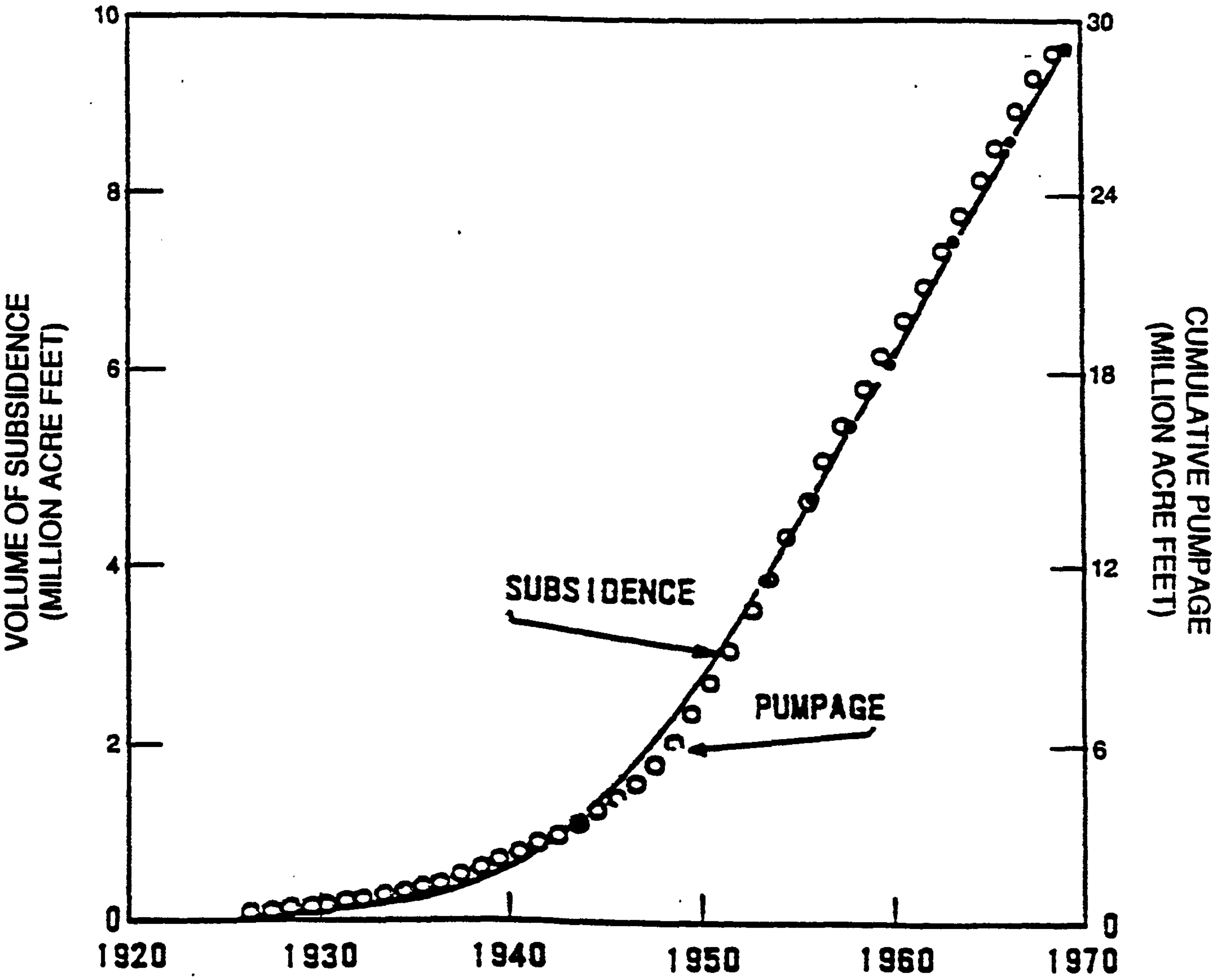
Modified from Williamson et al (1985), Table 9.

TABLE B.3

ESTIMATED PUMPAGE AND PERCENT OF PUMPAGE FROM COMPACTION OF LOWER AQUIFER FROM 1961-77 FOR THE MAJOR CENTRAL VALLEY SUBSIDENCE AREAS

Major Subsidence Area	Estimated Total Pumpage from Lower Pumped Zone (Million acre-ft.)	Estimated Volume of Subsidence (Million acre-ft.)	Estimated Percentage of Pumpage from Compaction
Los Banos - Kettleman Area	11.8	4.1	35
Tulare - Wasco Area	15.1	1.7	11
Arvin - Maricopa Area	12.6	0.56	4
Davis - Zamora Area	3.9	0.35	9

Modified from Williamson et al (1985), Table 9.



CUMULATIVE VOLUME OF LAND SUBSIDENCE AND PUMPAGE IN THE LOS BANOS - KETTLEMEN CITY AREA BETWEEN 1925 AND 1970

(MODIFIED FROM WILLIAMSON ET AL. 1985, FIGURE 37)

FIGURE B.18

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